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Air Arm DIVISION

Westinghouse

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Final Engineering Report

on

TERRAIN CLEARANCE RADAR SYSTEM

AN/APQ-82 (XY-1)

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Presented to

WRIGHT AIR DEVELOPMENT CENTER
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WESTINGHOUSE ELECTRIC CORPORATION
Air Arm Division
Baltimore, Md.

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FOREWORD

With the rapid growth of ground-based, long-range radar and IR installations, low-altitude approaches and penetrations have become increasingly important as a means of avoiding detection over enemy territory.

The probability of survival increases as altitude decreases, with an increasingly more than proportional benefit as the flight path drops below 500 feet. Maximum security can be achieved by following valleys or flight paths behind concealing enemy ridges. This action minimizes the effectiveness of enemy countermeasures.

LOW ALTITUDE RECONNAISSANCE

Low-level approaches to enemy territory from the sea can be made with greater security from detection if a terrain avoidance system is utilized to give the pilot a good landfall presentation in azimuth as well as in elevation. With this three-dimensional information, a flight path near water-top level is possible right up to the shore line. Subsequent reconnaissance can then be carried out at low altitude, taking advantage of protective topography where available.

TOSS BOMBING

The advantages of utilizing toss-bombing techniques can be effectively supplemented by low-level approaches prior to the toss maneuver. An effective terrain avoidance system can provide greater probability of escape.

SUPPORT

Missions which require the delivery of manpower and supplies near front line areas may be made with greater safety in the dark of night and obscured from enemy radar by concealing ridges.

With these future requirements in mind, Westinghouse began development on several systems designed for aircraft having a mission requirement of low altitude flight in either darkness or adverse weather. Flight tests then proved the feasibility of a three-dimensional system of presentation for the terrain avoidance radar.

An advanced version of the terrain avoidance radar, Terrain Clearance Radar Set AN/APQ-82 (XY-1), has been developed incorporating the parameters recommended by flight tests, greatly increased capabilities, and significant reduction in size and weight over the early flight test models. This report describes the design features and promising test results of this radar during laboratory tests at the Westinghouse Air Arm Division. Flight tests of this radar set, in the near future, should prove beyond a doubt that it is a long-needed addition to present-day navigation system.

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SECTION I

HISTORY

Westinghouse Air Arm Division has pioneered in the development and application of K_a-band radar for terrain avoidance systems. Initial efforts began under contract AF33(038)-22803[1/] in 1951 with the study of all-weather attack detection techniques for weapons systems. Terrain avoidance radar development began in earnest in 1954 as an outgrowth of a requirement found in this attack technique study. A field profile evaluation program using a modified Westinghouse commercial search radar was conducted at Mount Washington, New Hampshire[2/]. Later, a K_a-band breadboard model was built and flight-tested in a B-17 aircraft under contract AF33(616)-3248[3/]. The present project is a continuation of this work into the prototype stage.

1/ Final Report, Contract AF33(038)-22803 by Westinghouse Air Arm for U. S. Air Force, WADC, 15 March 1954, SECRET.

2/ Final Report, Contract AF33(616)-2248 by Westinghouse Air Arm for U. S. Air Force, WADC, 5 May 1955, SECRET.

3/ Final Report, Contract AF33(616)-3248 by Westinghouse Air Arm Division for U. S. Air Force, WADC, TR58-222 (soon to be published) CONFIDENTIAL.

SECTION II

SCOPE OF PROJECT

The purpose of this project was to develop a terrain avoidance radar suitable for flight-test evaluation. A brief study was to be made and a design specification prepared for customer approval; then a developmental model was to be built, using MIL-E-5400 as a guide.

It was the objective of this project to improve on the previous terrain avoidance radar in three respects:

a. To increase the display brightness to a level suitable for viewing in bright sunlight.

b. To increase the range sufficiently to allow a pilot adequate time to choose an optimum flight path and execute it in avoiding obstacles.

c. To develop an antenna which would be:

(1) More suitable for mounting in an aircraft.

(2) Better adapted to rapid scanning.

(3) Less difficult to manufacture to the required tolerances.

SECTION III

SUMMARY OF SYSTEM CHARACTERISTICS

3.1 GENERAL

In order to achieve adequate resolution with minimum antenna size, K_a-band was chosen. To minimize the need for pilot interpretation of the display, a 3-dimensional display, developed by Westinghouse and flight-tested in the previous terrain avoidance radar, was used. This display presents azimuth and elevation in true perspective with image color representing range.

3.2 COLOR RANGES

Three colors are used to identify three range segments. What these ranges should be is a function of aircraft speed, minimum clearance path to be flown, number of G turn, and maximum sustained climb angle. The method of determining the color ranges is explained in Appendix B. For the type of aircraft and mission under consideration for this radar (300 to 500 knots and a minimum altitude of 150 feet), these ranges were set as follows: red range - 0.25 to 1.5 nautical miles; yellow range - 1.5 to 3 nautical miles; green range - 3 nautical miles to 10 or 20 nautical miles.

3.3 RESOLUTION, SCAN RATE, AND SECTOR COVERAGE

Resolution, scan rate, sector coverage, and hits per beamwidth are interdependent, and the requirements depend on the same aircraft and mission parameters as color range. The product of resolution, scan rate, sector coverage, and hits per beamwidth is limited by the maximum pulse rate of the magnetron. In this radar set, adequate resolution with a beamwidth of 1.750 degrees and a scan rate of 0.75 frames per second for the type of aircraft and mission under consideration is achieved for a sector coverage of 10 degrees vertically by 35 degrees horizontally. The derivation of these parameters is fully covered in Appendix B.

3.4 RANGE AND SENSITIVITY

It can be shown (see Appendix B) that long range and extreme sensitivity are not necessarily desirable for terrain avoidance because of the finite beamwidth of the antenna pattern and the low altitude flight condition. For a capability of climbing over an obstacle, a 10-mile range is more than adequate. In 10 miles, an aircraft can climb 7,800 feet in a 7.5-degree climb. Terrain of such steepness and magnitude is rare if it exists at all. In 10 miles, a pilot would have adequate time to determine and execute a turn to avoid any reasonably proportioned obstacle likely to be encountered. This radar has a range gate of 10 and 20 miles which may be used. It is expected that large targets can be detected up to 20 miles. The most distant object visible from the Westinghouse Air Arm Division roof laboratory (where ground tests were performed) is a group of radio towers at 16.5 miles. These are easily detected by the radar set. It remains to be determined from flight tests whether the 20-mile range is desirable for either terrain avoidance or navigation purposes.

3.5 DETAILED SPECIFICATIONS

a. Antenna Characteristics

Antenna beamwidth	
Vertical	1.75 degrees
Horizontal	1.75 degrees
Scan Sector	
Vertical	10 degrees
Horzontal	35 degrees
Scan Rate	
Vertical	0.75 cps triangle
Horizontal	21.33 cps linear sawtooth

b. Transmitter characteristics

Magnetron type	MA-207
Frequency	34,900 ±350 mc
Power	70 kw (nominal)
Pulsewidth	0.25 microsecond
PRF	1365 pulses per second

c. Receiver Characteristics

System noise figure	13.0 db
Receiver gain	92 db minimum

Receiver i-f bandwidth	4.5 mc
Klystron type	Varian VA-97
Receiver tuning	Manual or afc
Local Oscillator frequency	45 mc above transmitter
Intermediate frequency	45 mc
Color ranges	
Red	0.25 to 1.5 nautical miles nominal
Yellow	1.5 to 3 nautical miles nominal
Green	3 to 10 or 20 nautical miles nominal
Range gate	
minimum range	0.25 ±0.1 nautical miles
maximum range	10 to 20 nautical miles
STC	Variable amplitude and shape

d. Indicator Characteristics

Presentation	Azimuth vs elevation in 3 colors to present range segments
CRT type	RCA C73703C storage tube
Marks	Aircraft's heading, horizontal reference

e. Input Requirements

115 volts 400 cps 3 phase Y connected at 7.5 amps.

28 volts dc at 2.7 amps.

Aircraft's vertical reference, 2 synchro inputs

Hydraulic fluid at 1000 psi and 0.5 gpm

Air pressure 40 psig

f. Environmental Conditions

Operating altitude	15,000 feet maximum
Operating temperature	-55 to +55 degree C

Vibration and shock per MIL-E-5400

g. System Components

1 - Antenna

1 - R-T, containing the following subunits.

1 Preamplifier

1 automatic frequency control

1 Modulator

1 Postamplifier

1 Power supply

1 Synchronizer

1 E-scope

2 X-scopes

1 Control panel

1 Set interconnecting cable

3.6 GROUND OBSERVATIONS

The completed system was installed in a work area on the roof of the Westinghouse Air Arm plant. Figure 1 is an actual photograph of the terrain visible when looking southeast from this location. The distance to Friendship International Airport Terminal Building is 1 mile. A water tank located 3 miles away can be seen in a gap in the background terrain to the right of the terminal building. This picture covers nearly the same terrain as the radar scan sector.

Figure 1. Photograph of Terrain Seen from Westinghouse Laboratory

A picture of the radar indication for the same area is shown in figure 2. The aforementioned water tower can be seen as a yellow object near the center of the radar picture. A green object can be seen on the right side of the radar picture. This object is a group of radio towers located near Annapolis, approximately 16.5 miles away. These towers are not visible in the terrain photograph, but can barely be seen with the unaided eye from the roof-top vantage point on a clear day. These towers have been observed with the radar through fog and moderate rain.

Figure 2. Terrain Avoidance Radar Picture of Terrain Seen from Westinghouse Laboratory

On one occasion, the set was operated during a series of thunderstorms. The rain was so heavy that at times the airport could not be seen visually. Under these conditions a solid red image of rain return was observed on the radar scope. As a crude correlation between visual and radar visibility, the airport tower was observed during these heavy rains. During more moderate but still heavy rainfall, the airport and water tower showed up clearly. Clouds were presented on the radar at ranges of 1 to 10 miles, although the radio towers were not seen during this period. After the weather cleared locally, a thunderstorm was observed on the radar image at

18 to 20 miles, the maximum range that is displayed.

Several observations confirmed that cloud painting is selective. At times the clouds visually appeared to be uniform, but the radar displayed only parts which apparently were more dense rain-bearing clouds.

While the above observations are qualitative, they demonstrate that the radar will present short-range obstacles adequately for terrain avoidance through clouds and moderate rain. Furthermore, heavy rain-bearing clouds present a characteristic spotty appearance which an experienced observer should be able to distinguish from the more solid image presented by terrain. A better evaluation of these factors should be accomplished during flight tests.

3.7 BENCH TEST DATA

Bench test data and detailed circuit information are covered in a separate handbook: "Radar Terrain Clearance Set AN/APQ-82(XY-1)."

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL

On the basis of ground tests, it appears that the present system will satisfactorily perform the terrain avoidance function. However, it should be flight-tested both to evaluate its performance in the air and to gain experience in flying from this type of display.

A flight test program to this end is to be conducted by the Weapons Guidance Laboratory, WADC, and Westinghouse early in 1959. The program is designed to test the radar for basic operating characteristics and from the operational standpoint by hooded flights using the radar display as a navigation aid.

4.2 DESIGN IMPROVEMENTS

In addition to exhaustive flight tests, it is recommended that the following design improvements be incorporated in any future terrain avoidance radar.

a. MAGNETRON

A magnetron with a higher duty factor should be developed to allow the use of faster scan rates. The corresponding reduction in time per scan would then permit a lower minimum altitude and reduce the amount of aircraft travel during one frame time. In straight-line flight and during gradual turns in 300- to 500-mph aircraft, the present system should prove satisfactory. Its usefulness in higher speed aircraft and during more rapid turns would increase in proportion to the scan rate.

b. CATHODE RAY TUBE

The feasibility of using a two-gun cathode ray tube to eliminate the need of multiplexing two images from one gun should be investigated. This action would considerably simplify the presentation system circuits, although the problem of registration of two guns might be troublesome.

Another major problem with presently available storage-type cathode ray tubes is the small grid base and limited tonal range. Various manufacturers are presently engaged in improving these characteristics with this problem in view. When improved tubes become available, a more satisfactory image will undoubtedly be obtainable on the profilometer display.

c. OPTICAL SYSTEM

The image brightness and consequent visibility in bright light is considerably better using a dichroic mirror optical system instead of a lens system. While the drawings and instruction manual show a lens system, a dichroic optical system was developed with Westinghouse funds at the close of the contract and supplied with the radar.

d. ANTENNA IMPROVEMENT

As a result of a reduction in the scope of the original contract, antenna development was suspended after construction of the first model. On the basis of results achieved, it is recommended that antenna development should be continued to find an optimum beamwidth and means to minimize beam deterioration that now occurs as a function of scan angle.

SECTION V

SYSTEM CHARACTERISTICS

5.1 PRESENTATION SYSTEM

5.1.1 X-SCOPE

The X-scope is the fundamental system display indicator. An azimuth angle vs elevation scan is presented and three colors are used to present the third dimension, range. The indicator thus presents a transverse profile of the terrain in front of the airplane in its true perspective. The display is observed on a ground glass viewing screen on which the image is projected from the cathode ray tube using a red and green filter system.

The X-scope chassis contains, in addition to the storage tube, the necessary high voltage power supplies and filament transformers. It also provides controls for vertical and horizontal centering, video gain, and display separation. Brightness, focus, collimating, and other controls for the viewing gun and erase gun of the storage tube are screwdriver adjustments accessible from the front panel.

5.1.2 X-SCOPE DESIGN

With the relatively slow frame rates of one per second or less that must be used, a long persistance image is required; however, long-persistance cathode-ray-tube phosphors have a decided disadvantage in their low brightness. In order to maintain both long persistance and high brightness, a storage-type tube was chosen. These tubes have a maximum brightness of 2000 foot-lamberts which is adequate for viewing in direct sunlight.

The secondary problem in developing the presentation system was the optical system design. To ensure simplicity and ease in interpretation of the color presentation, it was decided to use only three colors. Red represents short range (0.25 to 1.5 n.mi.), green represents long range (3 to 10 or 20 n.mi.), and the combination of red and green, yellow,

represents intermediate range (1.5 to 3 nmi.).

To avoid the complexity of optically combining three images, only two separate images are used, with the third being formed by optically combining the first two using appropriate time sharing techniques. Specifically, the combination is accomplished by placing a red filter in front of one image, a green filter in front of the second image, and then projecting the outputs onto a viewing screen.

Originally it was thought that selective image erasure could be used; however, in order to use selective erasure, it was necessary to use a single-writing-gun tube, since this was the only type available. This requirement made it necessary to switch one writing beam between the two images as a function of range. To make it possible for an object to appear in both images, it was necessary to effectively stretch all video returns to the width of the yellow range interval. A red range extending to 1.5 miles was selected on the basis of aircraft performance.

It appeared desirable to use a relatively short mid-range or yellow-range interval, since this minimized the probability of a noise pulse exceeding the threshold and increased the reliability of this range interval. The yellow range was therefore adjusted to extend from 1.5 to 3 miles. In this case, the writing beam painted the red image for returns received from ranges up to 3 miles. The video was stretched to a width of 1.5 miles, so that any video signal appearing at a range between 1.5 miles and 3 miles is painted not only in the red image, but also will last long enough to appear in the green image area. This same effect could have been accomplished by using a delay device to repeat the signal 1.5 miles later; however, video stretching was used since it offered a possibility that the relative brightness of the red and green image would vary in proportion to the range location of the target and the resulting time spent in painting each image, thus allowing perhaps two or three shades of orange to yellow to be identified. Target returns are only used to trigger a pulse generating circuit producing a video pulse of standard width and amplitude. Standardized video eliminated the possibility of brightness discrimination between weak signals or noise, and strong signals. However, it has been found that little brightness shading is apparent to the eye because of the characteristics of the storage tube when used at low scan rates and with nonselective erase. In nonselective erasing, the backing electrode is pulsed at a high rate to remove the stored

charge and cause a decay in a fixed time after writing. The fixed decay time is a function of the erase pulse width which therefore can be used to vary the persistance. If halftones are to be preserved in writing, an image must be produced which is brightest in the region just written, and thereafter is continuously fading out until rewritten. If halftones are sacrificed, a delayed droop characteristic can be achieved where in each area remains reasonably bright until shortly before it is rewritten. This feature is achieved by writing a saturated image which makes the earlier brightness decay less apparent. With the slow frame rate used in this system, it is necessary to use delayed brightness decay to achieve a picture with satisfactory continuity, otherwise, only a part of the picture would be visible at one time, which is unsatisfactory. Selective erase would eliminate this effect, preserving the halftones while achieving the delayed decay by erasing just ahead of the writing beam; however, other shortcomings of selective erase render it unsuitable for this system. As a result of the above considerations, it appears that brightness shading cannot be used with presently available storage tubes.

Originally it was thought that selective erasure could be used. Because of the long lead-time required to procure a storage tube and the short schedule of this project, the design of the final model of the X-scope was completed and construction was under way before a storage tube was received. When the storage tube arrived, tests disclosed that it did not perform as well as was claimed. The erase spot size was too large and could not be reduced to the desired size. The original plan was to erase just ahead of the writing beam to minimize flicker and increase the brightness, but the erase speed was too slow to allow erasure in synchronism with the writing beam. As a result of the fast erasure, a bright halo surrounded the erase spot. To avoid these difficulties, the alternative of nonselective erase was used.

If two returns at different ranges are received from one pulse, as when the beam is partially intercepted by a short range (red) and a long range object (green) they will appear as a yellow or intermediate range object. To eliminate this dangerous possibility, the video is gated so that only the first return from each pulse is displayed.

The center of the display represents the aircraft heading and is marked by a fixed mark on the viewing screen. To enable better

interpretation of the image, a set of horizontal lines driven from the aircraft vertical reference and stabilized in roll to the space horizontal plane are located in front of the image.

5.1.3 E-SCOPE

The E-scope or profilometer is an auxilary unit which provides additional information that can be utilized by a copilot or navigator. This information consists of aircraft altitude and a terrain profile. It also provides a video display for setting receiver gain.

The face of the E-scope contains cursor marks that indicate altitude for both the altitude and terrain displays. The altitude display cursor consists of a horizontal line, marked in intervals of 100 feet, in the upper half of the tube face. The profile display cursor consists of horizontal elevation lines which indicate heights in intervals of 1000 feet above or below the aircraft altitude. The corresponding radar range of these objects is indicated electrically by means of markers occurring at appropriate intervals during each sweep.

The aircraft altitude information is displayed once during each vertical cycle of the antenna, when the antenna is at its maximum depression angle.

The terrain profile information is displayed by sampling the echo returns from any one angular direction of the antenna's azimuth coverage. This angular direction may be selected by the operator by means of a calibrated profile selector dial.

The azimuth direction which is being profiled is continuously indicated on the companion X-scope by means of a brightened vertical line. With this provision, the operator may select from the X-scope the profile to be examined by turning the profile selector dial on the E-scope unit until the brightened vertical line coincides with the terrain to be observed. Altitude and range information for objects in the selected terrain sector may then be obtained from the terrain profile display on the E-scope.

5.2 ANTENNA

5.2.1 GENERAL

The antenna consists of a sectoral horn feeding a cylindrical parabolic reflector. The entire assembly is nodded mechanically by a hydraulic actuator to achieve the vertical scan. A unique method of folding and rolling up the horn is used to execute a rapid sawtooth horizontal scan using

rotary motion of the horn feed. The evolution of the horn is described in Appendix A. To feed the horn, a rotary joint which requires no contact between the horn throat and rotating feed was developed. A pillbox is used to direct the energy to the reflector and correct the wave front phasing. A magnetic pickup is placed in the rotary feed to sense the scan motion and furnish a pulse to trigger the indicator sweeps. A three-gang potentiometer is connected to the antenna so that the vertical motion rotates it to furnish the vertical sweep voltage to the indicators. The limits of the vertical scan sector are determined by the location of reversing microswitches actuated by the antenna. These switches can be adjusted to achieve the desired scan angle. The horizontal sector is determined by the horn configuration.

5.2.2 SCAN SECTOR AND BEAMWIDTH

A scan sector 10 degrees vertical by 30 degrees horizontal was chosen as a compromise between sector coverage and scan rate, while using a beamwidth no wider than is essential - in this case 1.75 degrees in both planes. The justification for these values is given in Appendix B. The horizontal scan sector is determined by the geometry of the rolled-up horn. Although the design objective was 30 degrees horizontal scan, the first model actually covered 35 degrees.

The horizontal scan is a linear sawtooth, while the vertical scan is linear with rounded limits for mechanical reversal of motion. Using a 0.25 microsecond pulse, a 1365 cps pulse repetition frequency, and a standard 1280 rpm (21.33 rps) gear motor driving the horizontal scan, 3.2 hits per beamwidth are achieved. With a 1.75-degree beamwidth and a 10-degree vertical scan, there are 5.7 vertical beamwidths per vertical scan, or 11.4 per complete frame. To allow a 50-percent vertical overlap of the beam pattern, 1/2 beamwidth of vertical travel per horizontal scan, or 22.8 horizontal scans per frame are required. The vertical scan speed must be

$$\frac{\text{Hor scans/sec}}{\text{Hor scans/frame}} = \frac{21.33}{22.8} = 0.94 \text{ cps.}$$

This value is the linear travel rate. If the vertical scan requires a 10-percent reversal time, the vertical scan rate will be $\frac{0.94}{1.1} = 0.88$ cps. It is necessary to use vertical overlap to minimize striping and to produce a more solid picture. It is also necessary to use the minimum number of hits per beamwidth that will give satisfactory coverage in order to allow maximum scan rates and minimize aircraft travel per frame. The product of hits per

beamwidth and beamwidths scanned per second is limited by the magnetron duty factor. The justification for the values used is given in Appendix B. Experience with radar using so few hits per beamwidth is limited. It is possible that 2 hits per beamwidth may prove adequate. This will be evaluated in the flight test program. A 2040 rpm (34 rps) gear motor driving the horizontal scan would allow 2 hits per beamwidth for a vertical scan rate of 1.36 cps. This system is designed so that the horizontal scan motor can be changed to accomplish either a 21.33 or 34 cps scan. The vertical scan rate can be varied by an adjustment on the hydraulic control valve.

To correlate the antenna coverage sector with the actual terrain coverage for purposes of aligning the antenna to scan some desired area or to center the scan about the aircraft's heading, a sighting fixture was provided. The sight was mounted on the antenna in a fixed position. Three front sights were provided and aligned with the center and each scan limit.

5.3 RECEIVER-TRANSMITTER

A very compact R-T unit was designed for mounting directly on the back of the antenna. While this adds weight to be rocked at the vertical scan rate, it helps balance the antenna and does not add to the scanned frontal area. In addition, mounting the R-T unit on the antenna eliminates a rotary joint and the subsequent r-f loss. The antenna development was stopped after the first breadboard model was completed. Consequently, the integrated antenna-receiver-transmitter was not completed. The R-T was connected to the breadboard antenna through a rotary joint. A stop equal in width to the rotating feed in the antenna scanner, which prevents energy from dividing between the limits of the scan as the scan passes from one limit to the other, causes most of the energy to be reflected back toward the magnetron when the scanner passes over the stop. To avoid damage to the magnetron window and minimize pulling, a ferrite isolator is used in the R-T unit.

5.4 MAGNETRON

Because of the near-grazing angles involved, high power is required to ascertain that each radar signal return exceeds the noise level of the receiving system. The two highest power magnetrons available for use in the K_a-band are the MA-207 and the 6799. Table 1 lists the characteristics of these two magnetrons.

TABLE 1
MAGNETRON CHARACTERISTICS

CHARACTERISTIC	MA-207	6799
Peak Power (KW)	60	150
Pulse width (μsec)	0.25	0.1
Duty cycle	0.0004	0.0002
Average power (watts)	24	30
PRF (max. pps)	1600	2000

It can be shown (see appendix B) that the MA-207 is more suitable for terrain avoidance radar. The use of the 6799 would also add approximately 50 pounds to the weight of the system.

5.5 SYNCHRONIZER

The synchronizer provides the timed pulses needed to correlate and synchronize the various functions of the terrain avoidance radar.

To obtain a stable prf (pulse repetition frequency) and an accurate correlation between the transmitted pulse and the range marks on the E-scope, a crystal controlled 1-mile mark generator was used. The output is obtained from a frequency divider chain. This type circuit is more complex than others, but has improved stability. One important advantage is that most of it is transistorized and designed to operate satisfactorily with any transistor within the manufacturer's specifications. The circuits are temperature stabilized and have been tested and proved satisfactory over the range of -55 to +100° C.

5.6 POWER SUPPLY

Because of the use of direct coupled vertical deflection circuits in this system, extremely stable supply voltages are required. Drift with temperature, input voltage, or load must be kept to a minimum, since this will show up as a change in the vertical relationship between the aircraft heading, which is marked by a fixed marker engraved on the viewing screen, and the terrain displayed.

Temperature effects upon the supply are virtually eliminated by means of individual ovens which entirely enclose the feedback amplifier control circuits and maintain the circuit components at a temperature of 85

± 2° C.

The regulation and ripple of the supplies are shown in table 2.

TABLE 2

POWER SUPPLY RATINGS

SUPPLY VOLTAGE	CURRENT RATING (ma.)	FULL LOAD RATINGS	
		RIPPLE (percent)	REGULATION (percent)
+400	50	0.03	±3.8
+300	800	0.025	±0.01
+150	800	0.025	±0.01
+22.5	50	0.3	±3.3
-150	800	0.025	±0.01
-300	200	0.025	±0.01

APPENDIX A

ANTENNA DESIGN

The present terrain avoidance system requires scanning in both azimuth and elevation. A system requirement for a sector courage of 30 degrees horizontally by 10 degrees vertically was established (see appendix B). Mechanical scanning is feasible for the slower scan in one plane. To further simplify the problems of mechanical scanning, it appeared desirable to perform the mechanical scan in the vertical plane where the required travel is least. A rapid scan in azimuth was therefore required. The rapid scan could have been performed in elevation, thus limiting the required scan to 10 degrees and easing the problem of beam deterioration for the rapid electrical scan at the expense of the mechanical scan. Preliminary investigation indicated that an acceptable beam could be achieved over a 30-degree scan.

In order to obtain a scanning pencil beam to satisfy the above conditions, a horizontal scanning line source could be mounted at the focal line of a parabolic cylindrical reflector and the vertical scan can be accomplished by rocking both the reflector and line source.

Various methods were considered to achieve rapid scanning in a plane. These are:

a. A sectoral horn folded in such a way that the direction of peak radiation can be moved through an angle in space by continuously rotating a small feedhorn in a single direction.

b. A slotted waveguide with a moving backwall whose position may be varied thereby changing the velocity in the waveguide.

c. A controllable r-f phase shifter, such as those made with ferrites, where the phase shifting is controlled by a magnetic field varying according to the same amplitude and frequency.

d. Trough waveguides[1/] which employ an electromechanical means of beam scanning.

A sectoral horn described in paragraph a., above, has an advantage over the moving backwall type in that scanning is produced by a continuous rotary motion of the feed, whereas in the latter, the backwall is moved to and fro. For the rapid scanning rates required, the rotary motion presents less mechanical problems; however, in contrast, the inherent aberrations that exist in a folded sectoral horn do not exist in the moving backwall type.

It was found that either of the above is better able to satisfy the demands of the terrain avoidance specifications than the ferrite-type scanning antennas for two reasons. One is the difficulty in producing the magnetic field to effect the necessary phase shifting, and the second is the adverse effect of temperature upon the phase shifting characteristics of ferrites.

The electromechanical scanning means, using a trough waveguide, looked promising as a rapid scanner because a reciprocating motion is not necessary. However, not enough information was available on this type of antenna to determine its feasibility as a scanning-line source in an antenna for a terrain avoidance system. In view of that fact, it was decided to use a folded sectoral horn. A scanning rate of at least 20 scans per second is required. Furthermore, the beam pattern specifications are not so severe that a sectoral horn would not be the most practical as far as performance, volume, and weight are concerned.

The most common type of sectoral horn[2/] is used to focus the energy from a point source placed at the focal point of a reflecting surface, and confine it between conducting plates into a cylindrical wave front as is emitted by any line source. The folded, double-layer sectoral horn reduces the reflections back to the feed.

The following requirements were established for a focusing element such as a sectoral horn.

1/ Walter Rotman, "Electromechanical Scanning by means of Trough Waveguides" (Classified) Georgia Inst. of Tech. Atlanta, Ga., Symposium Record of Georgia Tech, SCEL Meeting on Scanning Antennas pp 369-381, December 1956.

2/ S. Silver, "Microwave Antenna Theory and Design", MIT Rad Lab Ser. McGraw Hill Book Co., Inc. New York, N. Y. Vol. 12, pp 459-464; 1949

a. Aberrations should be small so that the beam divergence is caused mainly by the usual wavelength-aperture relationship.

b. The locus of positions of the moving feed should fall as nearly on the arc of a circle centered as nearly on the center of the focusing element as is mechanically feasible.

c. Energy absorption and back reflections of the sectoral horn should be held to a minimum.

d. The design should be such that production is mechanically feasible and, in the interest of reasonable cost, complexity should be held to a minimum.

Early systems employing this folded type of construction include the Robinson and Schwartzschild Scanning Feeds[3], both of which are electromechanical scanning devices.

Another approach investigated was to produce wide-angle scanning by means of circular symmetry in the antenna. Iams[4] has built a circular reflector with a correction element. This scanner covered an 82-degree field 20 times per second with a beam 1.1 degrees wide up to ±30 degrees, increasing to 2.3 degrees at ±41-degree scan. Construction consisted of a double-layer, circularly symmetric type with a toroidal bend substituted as the reflector. A lens which corrects spherical aberration of the system was moved with the waveguide input. The multiple feeds were switched sequentially so that a rotary motion was accomplished. However, in spite of the rotary motion, the large mass of the lens elements presented mechanical problems. Furthermore, the beamwidth was greater than that for a parabolic reflector of the same size.

Another sectoral horn type which was investigated is the Chait Microwave Schmidt System[5]. This type is a double-layer pillbox with a non-centric dielectric lens of the Schmidt type to correct for the aberrations of a circular

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3/ W.M. Cady, M.B. Karelitz, and L.A. Turner, "Radar Scanners and Radomes". M.I.T. Rad. Lab. Series, McGraw Hill, Vol 26, pp 45 - 61.

4/ H.B. Devore and H. Iams, "Microwave Optics between Paralleled Conducting Sheets," RCA Rev Vol 9, pp 730-732, December 1948.

5/ H.N. Chait "A Microwave Schmidt System" Naval Res. Lab. Washington, D.C. NRL No 3889; May 1952. Also see "Wide Angle Scan Radar Antennas" Electronics Vol 26, pp 128-32, Jan. 1953

cylindrical mirror. It showed possibilities in the antenna application here, but a method of folding to allow rotary motion of the waveguide feed could not be conveniently fabricated.

Another way which was studied was the use of the geodesic principle[6/] to construct flat conducting sheets into special geometric shapes. Also, the Luneberglens[7/] principle was found to have been used in rapid scanners. These types of scanners were found to be difficult to build to the tolerances required for the performance desired.

Another type of antenna which could be used is a modified Foster Scanner serving as a rapid scanning line source located at the focus of a parabolic cylinder. This whole assembly could be scanned slowly. Further investigation is necessary to determine the feasibility of this type of line source as in a terrain avoidance system. One model was built with beamwidth of less than 2 degrees and sidelobe supression of 20 db or more over a scan range of 45 degrees. It is believed that the large size of this model could be considerably reduced for smaller scan range.

The type of sectoral horn used in the present design is a two-layer folded type. Basically, the waveguide feed swings through a circular arc which, at all positions, is as close to the focus of the reflector as is mechanically possible. A circular reflector[9/] principle was chosen in order to obtain better uniformity of beam pattern throughout the scan angle. By observation of figure A-1, it can be seen that if the feed-position locus was an arc of circle, the center of which concides with that of the circular

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6/ B. Berkowitz and J. D'Agostino, "A Geodesic Antenna for Flush Mounted Applications"(Classified) Georgia Inst. of Tech., Atlanta, Ga., Symposium Record of Georgia Tech, SCEL Meeting on Scanning Antennas pp 283-293; December 1956

7/ R.J. Rinehart, "A Family of Designs for Rapid Scanning Radar Antennas" Pro IRE, Vol 40 pp 686-688, June 1952

8/ R.C. Honey and E.M.T. Jones, "A Mechanically Simple Foster Scanner", Trans, IRE, Vol AP-4 pp 40-46, January 1956

9/ Ashmead and A.B. Pippard, "The Use of Spherical Reflectors as Microwave Scanners" JIEE (London) Vol 93 pt IIIA 1946, pp 627-632.

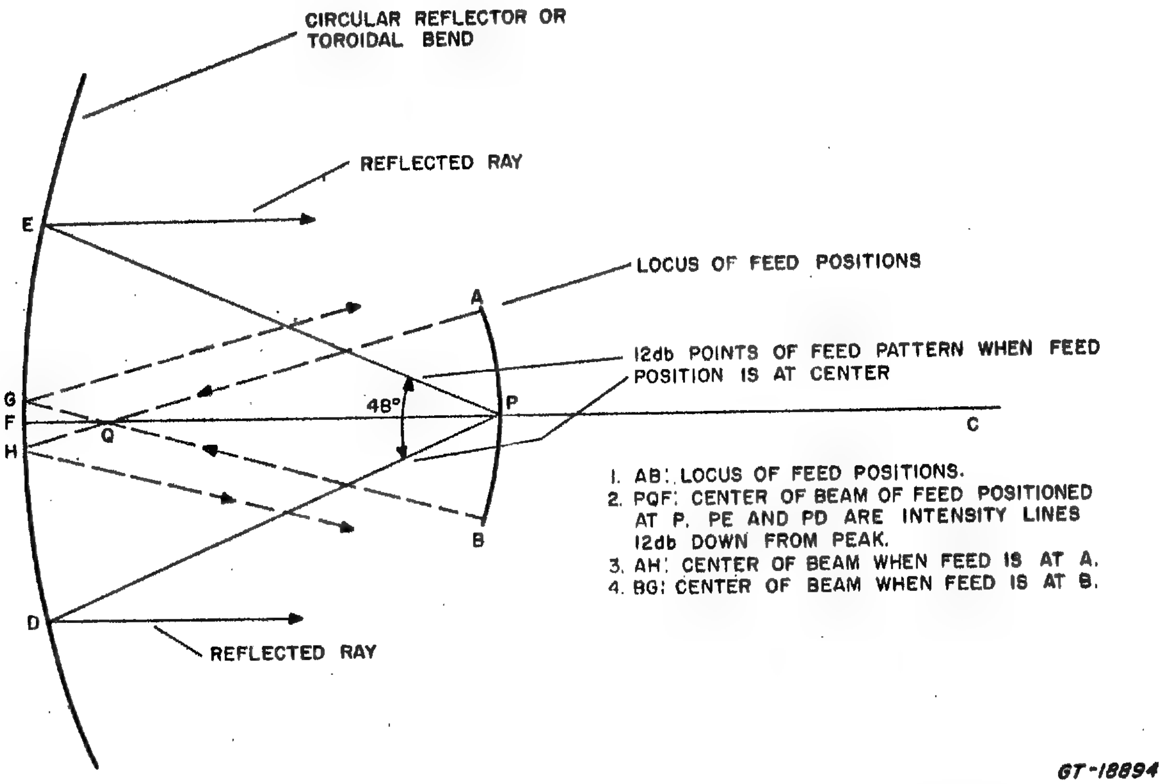


Figure A-1. Simplified Layout Showing Optics of the Folded Pillbox

reflector, the beam pattern would be independent of feed position as long as the reflector intercepted all of the significant energy from the feed. In such a circularly symmetric system, only the on-axis aberrations, such as spherical, would be present. Off-axis aberrations, such as astigmatism and coma, would be absent.

As can be seen later in the discussion, it would be quite difficult to find a way to fold such a configuration into a shape such that a rotating waveguide feed could be employed. Consequently, the feed locus arc was made to curve the other way, as seen in figure A-1, in order to achieve the above with relative simplicity, but with a sacrifice of beam pattern uniformity. Of course machining tolerances also can contribute to nonuniformity of beam over the scan.

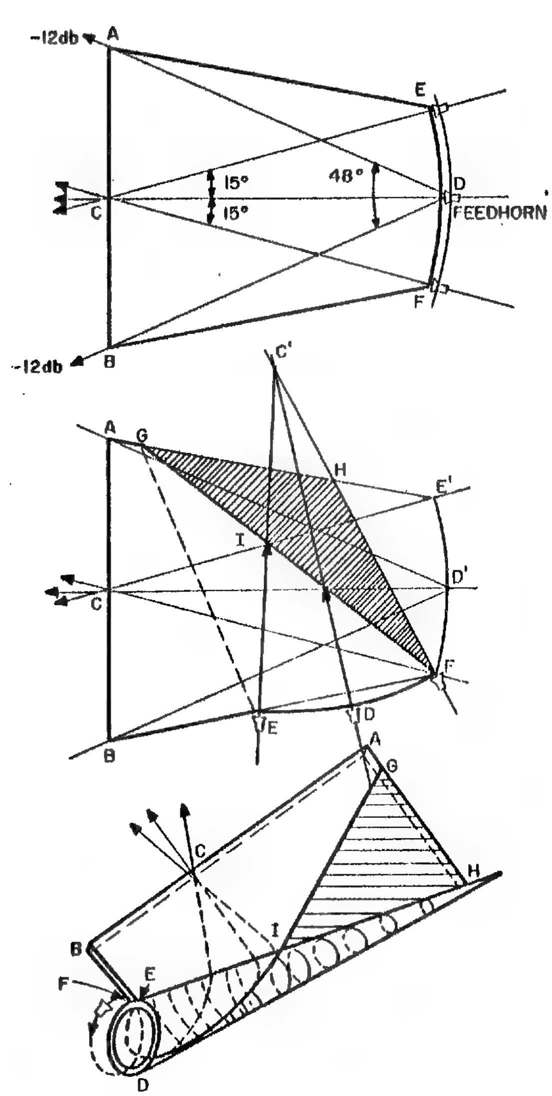
The basic geometry of the present optical system design is shown in figure A-1. The feed swings along the arc $\overline{AB}$ with the center of the beam

from the feed being normal to this arc. While the feed is stationed at point P, the center of the beam is directed toward point F on the reflector, and the part of the beam which is 12-db down from the peak intensity strikes the reflector at points D and E. The reflected rays from points D and E are slightly off parallel to the reflector axis, due to spherical aberration. While the feed is at point A, the center of the beam is directed toward point H. The reflected rays would be very nearly parallel and at an angle of 15 degrees from the reflected rays produced by the feed while at point P. While the feed is at point B, the reflected rays are also at angle of 15 degrees in the opposite direction from the reflected rays produced by the feed while at point P.

Figure A-2A is a schematic diagram of the arrangement shown in figure A-1, without the circular reflector. Figure A-2B shows the position of a backwall reflector and the change of the position of horn feed arc. Figure A-2C illustrates how the sectoral horn can be rolled up so that the waveguide feed can be rotated as previously described. From figure A-2 it can be seen that the beam position would progress only one way and then suddenly jump back and start over as in a sawtooth waveform.

A circular toroidal bend is used instead of a circular reflector. Diverging rays, emanating from the straight edge of the sectoral horn shown schematically in figure A-3, enter the toroidal bend and emerge collimated at the straight edge AB as shown in figure A-2C. The rays are confined to this small circular fold to prevent reflections back to the waveguide feed. Flanges or horn sides are fastened along the straight line aperture in order to effect a better impedance match to space. This aperture provides the line source which is the feed placed at the line focus of a parabolic cylinder. As a result, a pencil beam that can be rapidly scanned in azimuth can be produced.

In designing and fabricating the antenna, the dimensions must be held within tight tolerances in order to minimize r-f phase errors. The optical paths in the sectoral horn are closely dependent on such factors as backwall position, radii of the circular toroidal bend, and spacing between any of the inner adjacent surfaces. The first approach was to use sheet metal. Two sheets similar to the illustration shown in figure A-2B were cut. Then an attempt was made to roll them into a configuration as shown in figure A-2C. The control of the conical dimensions was inadequate, and furthermore, a backwall had to be placed in its proper position. The plane parts that were



A. SECTORAL HORN

1. AB DETERMINED BY DESIRED BEAMWIDTH
2. CD DETERMINED BY FEEDHORN PATTERN AND DESIRED BEAM PATTERN
3. EF DETERMINED BY DESIRED SCAN SECTOR

   EF IS AN ARC OF A CIRCLE WITH RADIUS CD

   EF IS ALSO THE STRETCHOUT OF A RIGHT CONE WITH SLANT HEIGHT CD. RADIUS OF THE CONE BASE IS THUS FIXED AND MAY BE COMPUTED

B. FOLDED SECTORAL HORN

1. FOLD ALONG ANY CONVENIENT LINE, SUCH AS FG MAKING E FALL ON BF.
2. SINCE A SECTORAL HORN IS COMPOSED OF PARALLEL PLATES, THE HORN IS EFFECTIVELY FOLDED BY PLACING A BLACKWALL FG BETWEEN THE PLATES. THE RAY PATHS ARE THUS FOLDED AND THE RAYS REFLECTED FROM FG.
3. LOCATE THE CONE APEX, C'.

   ONLY ABFG IS NECESSARY TO THE ANTENNA ACTION. EFI IS THE TRUNCATED SECTION OF THE CONE REQUIRED. FGH IS ADDED FOR STRUCTURAL REASONS.

C. SECTORAL HORN FOLDED AND ROLLED UP.

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Figure A–2. Development of the Rolled–Up Sectoral Horn

reasonably light in weight were not stiff enough, consequently reinforcing ribs were necessary. It was obvious that if these ribs were attached with screws, then the screws would produce intolerable electrical discontinuities on the inner adjacent surfaces. Welding of the ribs onto the plane sheets was tried and produced intolerable warping. Consequently, the use of sheet metal was abandoned.

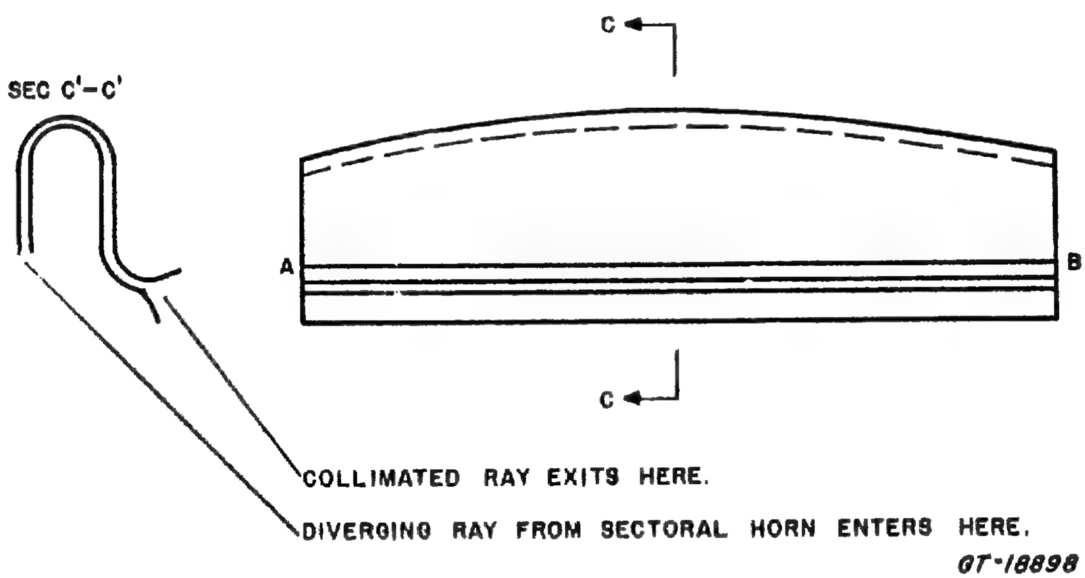

Figure A-3. Folded Circular Reflector

In order to satisfy the above conditions, the major parts of the assembly were machined. The conical parts consisted of the outer truncated cone, and the inner cone. The spiral backwall was mounted on the outer surface of the inner cone. The data used to determine the position of the spiral backwall were calculated on an IBM computer. Two parallel trapezoidal plane plates were machined with outer ribs to effect adequate stiffness, and were assembled onto flanges on the outer cone. The inner or propagation surface of the piece which provides the outer surface of the circular toroidal bend geometrically resembles the inner surface of a circular arc whose cross section is semicircular and whose sides extended in such a way that both the entrance and exit parts of the surface are straight. See the schematic diagram in figure A-2 and also figure A-3. Dimensional stability of this piece is achieved by circular flanges on the outside. The piece which provides the inner surface of this circular reflector is a negative of the propagation surface of the piece just described. Each of these parts are machined and are bolted both to the parallel plates and to each other. Flanges are bolted to the exit of the circular reflector in order to produce a better impedance match to space. The parabolic cylindrical reflector is of lightweight construction consisting

of sheet metal strengthened by plastic honeycomb material.

The waveguide feed or feedhorn is part of two concentric surfaces of revolution which are part of the rotor. Two septums between the surfaces and small sectors of the surfaces themselves form this feedhorn. The horn electrically couples the cylindrical waveguide of a rotary joint to the circular spacing entrance into the sectoral horn. The hollow space of the rotor axle serves as the above-mentioned cylindrical waveguide and extends to a stationary waveguide junction which is supported by a cap that screws onto the outer cone. This cap contains the two ball bearings which support the rotor.

This rotor is driven at approximately 20 rps by a small motor housed inside the inner cone. Also, a magnetic pickoff is attached to the supporting plate on which the motor is mounted to provide a sweep synchronizing pulse at the beginning of each scan.

The sectoral horn and the parabolic cylinder were then mounted as an assembly on a support in such a way that this assembly could be rocked by a hydraulic actuator or electric motor. This rocking action provides the slow vertical or elevation scan.

In the experimental setup, a hydraulic actuator was used. It was controlled by a servo electro-hydraulic valve. This valve has the property of controlling hydraulic pressure at a magnitude that varies as its electrical input. As a result, the frequency of the vertical scan can be easily varied. The scan amplitude is determined by positions of two microswitches which control the signals to the control valve. Furthermore, the sectoral horn reflector assembly is mechanically linked to a potentiometer such that an electrical output corresponding to the antenna vertical scan position is provided for driving the indicator sweeps.

In the final measurements of the assembled antenna, the following results were demonstrated:

a. The vertical or elevation pattern is shown in figure A-4. The beam is 1.5 degrees wide at the half-power points. Notice that the pattern is reasonably smooth to more than 20 db below the peak intensity. This property is required to minimize signal returns from level terrain in the foreground.

b. The azimuth or horizontal pattern is shown in figure A-5. The beam is 1.5 degrees wide at the half-power points at the extreme scan positions,

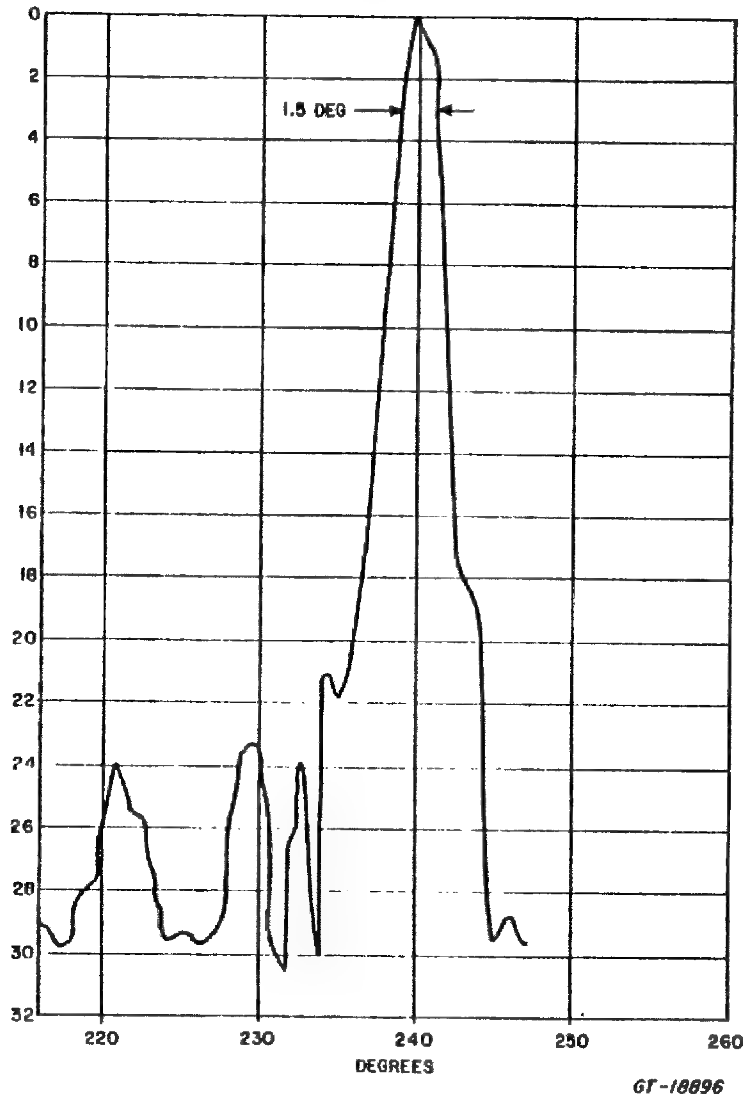

Figure A-4. Antenna Vertical Pattern

wheras it is 3.25 degrees at the center of the scan range. This indicates that the phase front from the pillbox is more distorted when the waveguide feed is in the center of the scan. Referring to figure A-1, it can be seen that if the point P is at the virtual focus of the circular reflector, the wavefront from the reflector should be less distorted than when the feed is at positions A and B; however, the optical paths from the feed, at any scan

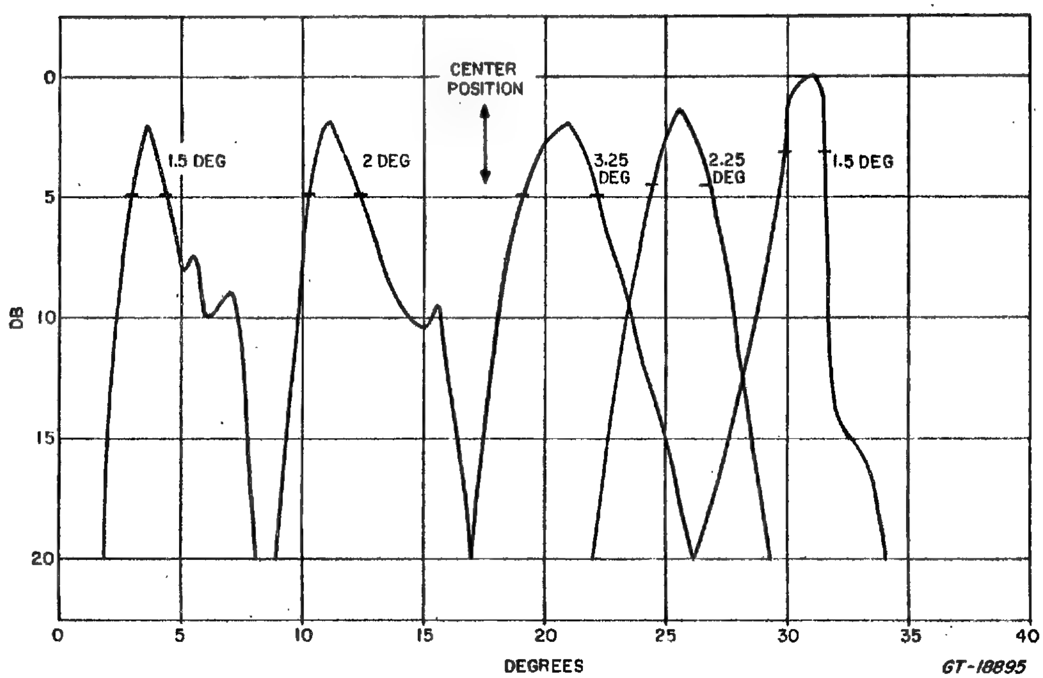

Figure A-5. Antenna Horizontal Pattern

position, to the reflector can be influenced by variations of the spacing between the surfaces of the pillbox, and the accuracy of the backwall position. Consequently, it is entirely possible that variations due to machining tolerances could have produced the measured azimuth beam patterns. Furthermore, a slight shift of the feed locus away from the reflector theoretically could reduce the aberrations while the feed is at positions A and B, but at the expense of increasing the aberrations while feed is at position P.

The performance of this antenna is adequate for the present system. The horizontal beamwidth is somewhat wide at the center of the horizontal scan range, but this could have been improved by further investigation of the phase errors caused by dimensional variations due to machining tolerances. If beamwidths of less than 1 degree and sidelobe supression of greater than 20 db are desired over a 30-degree scan range, the present scheme is considered hardly feasible because of the inherent aberrations of the basic optical system used.

APPENDIX B

OVERALL DESIGN PARAMETERS

The ideal terrain avoidance system should have the following basic characteristics:

a. Scan rapidly enough so that aircraft travel between successive scans is negligible. A scan of this relative rate would approximate the effect of a continuous view of the entire area, simulating the pilots view through the aircraft windshield.

b. Cover a large angular field of view to enable a better choice of flight path.

c. Narrow beamwidth to enable good resolution.

d. Have a certain minimum number of transmitted pulses per beamwidth of scan to be certain of detecting small targets. It would be desirable to have many transmitted pulses per beamwidth to increase sensitivity and improve signal to noise discrimination, but it will be shown that this is impractical.

Each of these desirable characteristics will increase the required pulse repetition frequency of the radar set. The maximum prf is limited by the duty factor of available magnetrons. If a rectangular sector is covered,

$$\text{prf} = N \times \frac{H \times W}{(BW)^2} \times \text{frames/sec.}$$

where

N = number of hits per beamwidth

H = height in degrees of sector covered

W = width in degrees of sector covered

BW = antenna beamwidth

The minimum practical number of hits per beamwidth was chosen to allow maximizing the other factors. Experience with so few hits per beamwidth is limited; however, Westinghouse found that three hits were satisfactory in a

previous terrain avoidance system. Provision was made to change the scan speed so that the radar can be operated with two hits per beamwidth to determine if this number appears equally satisfactory. The only objection to the use of so few hits is that it eliminates any form of display integration which would enhance sensitivity and range. On the other hand, it will be shown that adequate range is achieved and a sensitivity greater than required will only deteriorate resolution due to beam broadening.

The number of frames per second to be scanned must be determined in terms of aircraft travel between scans and must be made no greater than necessary, to allow a maximum field of view with adequate resolution. Thus, antenna beamwidth may be chosen on the basis of the resolution necessary to fly the required minimum clearance. The minimum number of hits per beamwidth is determined by beamwidth and prf. The prf is in turn determined by the magnetron. The sector coverage (Height and Width) and frame rate are then the interdependent parameters which may be varied to determine an optimum compromise for the aircraft under consideration.

The scanning raster is shown in figure B-1. A more meaningful equivalent of frame rate is distance traveled per frame. The time t_W required for one line scan is

$$t_W = \frac{N \times W}{BW_W \times prf},$$

where

BW_W = antenna horizontal beamwidth

The time t_H required to scan one raster is

$$t_H = \frac{t_W \times H}{BW_H} = \frac{N \times W \times H}{BW_W \times BW_H \times prf},$$

where

BW_H = antenna vertical beamwidth.

If, as in this radar, the time of one vertical scan = 2 t_H to allow 50-percent vertical overlap of beam to minimize striping, an up and down scan is used, and a 10 percent reversal time is required,

then $t = 2 \times 2.2 \times t_H$,

where

t = the time of one complete scan cycle,

and

$$D = V\ t = \frac{V \times 2 \times 2.2 \times N \times W \times H}{BW_W \times BW_H \times prf},$$

where

D = distance traveled per scan cycle.

V = aircraft velocity.

This equation may be rearranged

$$\frac{H \times W}{D} = \frac{BW_W \times BW_H \times prf}{4.4 \times N \times V}.$$

The indepent parameters are:

N (minimum)

prf (determined by the magnetron)

The dependent parameters are:

V (aircraft variant)

BW_W (horizontal resolution or horizontal clearance varient)

BW_H (vertical clearance variant)

Let prf = 1365 cps, N = 2,

Then

$$\frac{H \times W}{D} = \frac{1365 \times BW_W \times BW_H}{8.8\ V} = \frac{155 \times BW_W \times BW_H}{V}$$

Thus, when beamwidth and aircraft velocity are known, the quantity $\frac{H \times W}{D}$ is equal to a constant and the problem becomes one of finding an optimum compromise between these parameters.

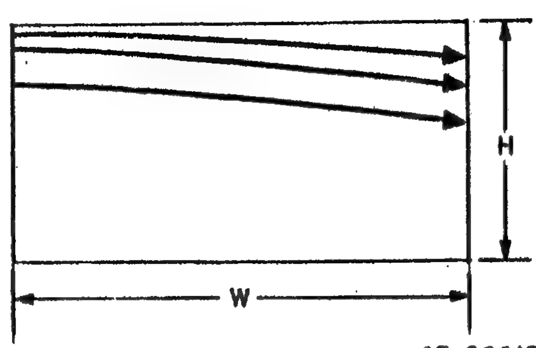

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Figure B-1. Scanning Raster

Assuming $BW_W = BW_H$, the ratio $\frac{H \times W}{D}$ is plotted in figure B-2 for various dependent factors. For a 800-foot-per-second aircraft and a beamwidth of 1.75 degrees.

$$\frac{H \times W}{D} = 0.595 \text{ or } H \times W = 0.595D.$$

If a sector 30 x 10 degrees is chosen,

$$D = \frac{H \times W}{0.595} = \frac{30 \times 10}{0.595} = 504 \text{ ft.}$$

This is the travel between successive scans at the upper and lower limits of the scan. This travel decreases to 252 feet at the center of the scan. The time for a complete vertical scan then is

$$t = \frac{D}{V} = \frac{504}{800} = 0.63 \text{ second.}$$

The time for one horizontal sweep,

$$t_W = \frac{N \times W}{PRF \times BW} = \frac{2 \times 30}{1365 \times 1.75} = 0.025 \text{ sec.}$$

or a 40 cps rate.

The horizontal sector coverage is fixed by the antenna configuration and cannot be varied. The actual coverage of the antenna turned out to be 35 degrees. The beamwidth required is a function of the minimum clearance path to be flown. A beamwidth of 1.75 degrees appeared to be adequate for flights at a minimum clearance of 150 feet. One beamwidth then equals 45 feet at 0.25 miles (minimum range). Resolution to perhaps 0.5 beamwidth may be achieved in practice, but resolution to one beamwidth would still be acceptable. In order to use the magnetron without current regulation, it is necessary to use a prf somewhat below the maximum rating to ensure satisfactory magnetron life. A prf of 1365 cps was used. This allows the line voltage to rise 5 percent above normal without exceeding the maximum average power rating of the magnetron.

When 35-degree horizontal coverage is substituded for the 30-degree coverage used in the computation of the horizontal scan rate, the rate becomes 34.4 cps. A rotary motion at this rate is required to perform the scan. 2040 rpm or 34 rps was found to be the nearest speed attainable, using a standard gear motor. The vertical scan cycle time thus becomes 0.735

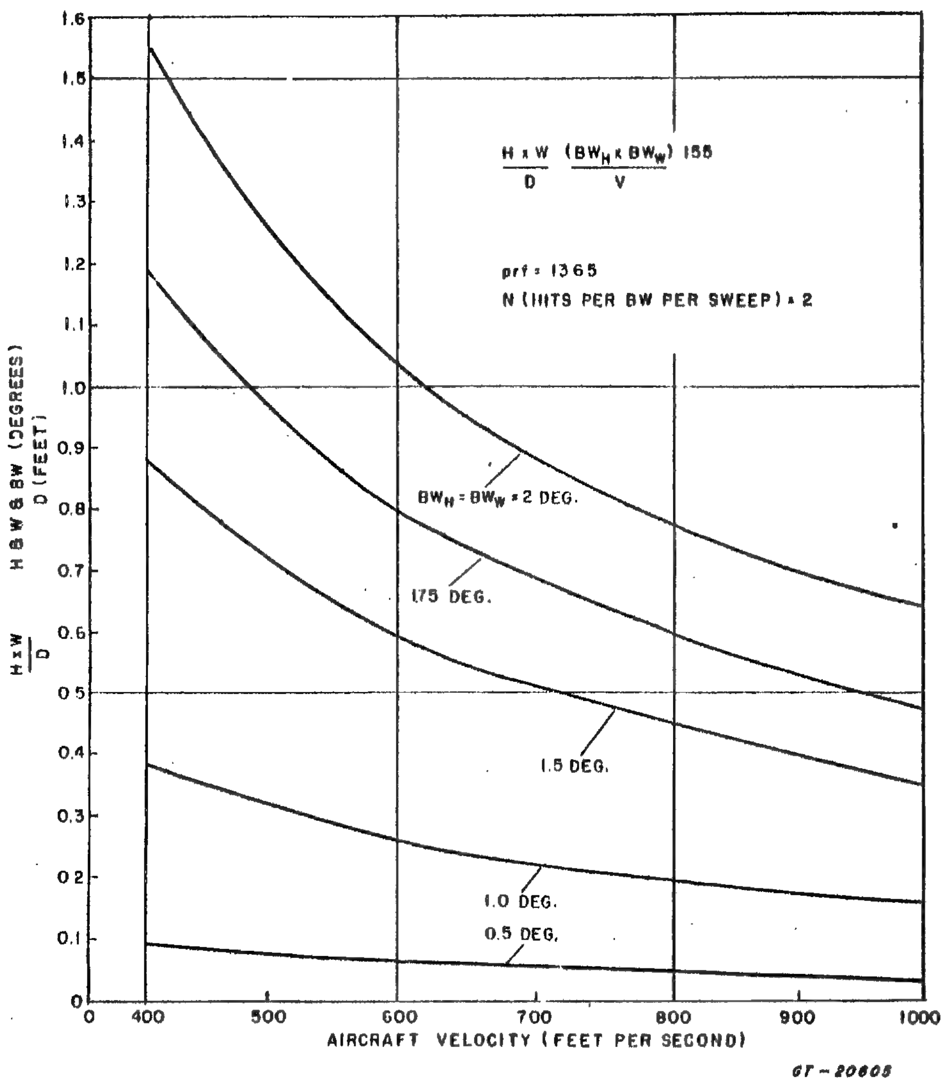

Figure B-2. Ratio $\frac{H \times W}{D}$

second (scan rate 1.36 cps). The aircraft travel per frame time then becomes 294 feet at the vertical center and increases to 588 feet at the upper and lower limits of the scan.

To determine the range (distance from object) at which the aircraft must be steered to maintain minimum clearance, it is necessary to determine the time required to perform the requisite climb or turn. Obviously, a finite delay - reaction or response time - exists between the time the pilot determines he must maneuver his aircraft to avoid an object and the time that

action is completed. Under the worst conditions, an object will appear in the red color band (range) just after scanning. The time needed to perform the requisite climb is then the sum of frame time, pilot's response time, aircraft response time, and aircraft climb time. Response times of 2 seconds for the pilot and 1 second for the aircraft appear adequate. It was determined that the time for a complete scan cycle was 1.18 seconds for the slow rate and 0.74 seconds at the faster rate. The time lag between the appearance of an object at the upper limit of the display just after scanning of the area and the start of the pull-up is therefore the sum of these times or 4.18 and 3.74 seconds with a slow or fast scan respectively.

The time period yet to be considered is the time required to climb over the obstacle. In this case, it is necessary to specify the type of approach, the minimum clearance, the allowable number of G pull-up, the aircraft speed, and maximum sustained climb angle.

In the normal type of approach, it is desirable to keep the top of any obstacle under observation, otherwise the extent of the obstacle and the subsequent maneuver necessary to clear it are unknown. In the case of a long slope or a series of ridges of increasing height, the picture would be green to the upper limit of the display, yellow at some lower angle of elevation, and red at a still lower point; green indicating objects 5 degrees above the flight path, yellow objects up to the flight path, and red objects that extend to some point below the flight path. In the case of a turn where an object in the red range may extend to the top of the display, it is presumed that it will have been monitored during the approach, even though off to one side of the display centerline.

With the display used, where segments are identified by colors, range is accurately known where the display changes color. If red is chosen for the shortest range, the pilot must steer to keep all red targets below him. It is desirable to make the range below which this clearance is maintained the minimum consistent with safety. This clearance is displayed as an angular clearance. For a given aircraft and speed, the range for which minimum angular clearance is steered is a function of the number of degrees an obstacle will be allowed to extend above the flight path in the preceding range interval or display color. The minimum angular clearance is limited by antenna beamwidth. The shorter the range for which the desired clearance is steered, the larger the clearance angle becomes, and the wider the

permissible beamwidth. For a given beamwidth, the shorter the range at which clearance is maintained, the smaller the clearance may be.

Two parameters, minimum clearance and maximum angle which an obstacle is allowed to extend above the flight path, up to the point where minimum clearance is steered for, must be selected on the basis of expected aircraft performance. Once these are selected, the range for which minimum clearance is steered can be determined on the basis of ground speed, maximum number of g's pull-up, and the maximum constant-speed climbing angle.

It appears that if the system is designed so that the aircraft can clear an obstacle which extends 5 degrees above the flight path at the range where the image turns red, the aircraft will have a capability in excess of normal needs to handle emergency situations as severe as are likely to be encountered. For purposes of system design, it will be specified that a path of minimum clearance of 150 feet will be flown and that an obstacle extending to the upper limit of the display will be allowed to turn red before clearance is initiated. The aircraft should then be able to clear the obstacle by 150 feet using nominal maneuvers. A 1-g pull-up will be specified. One-g pull-up curves are plotted in figure B-3. A delay of 4.2 seconds for aircraft response, pilot response, and the time required to scan one frame is included. It should be noted that the difference between the frame time for the slow and fast scan is relatively unimportant compared to the total delay, so the larger delay is used.

This system is intended for aircraft in the 500- to 700-foot-per-second class. Curves for these two aircraft speeds are shown along with those of a 1000 foot-per-second aircraft for comparison. To determine where the limit of the red range is and thus the range for which minimum clearance must be steered, proceed as follows. Select some range from the table on figure B-3 and read the corresponding height of an object 5 degrees in height. Add 150 feet. On the pull-up curve for the proper aircraft speed, determine if this altitude can be attained at the selected range. By a series of trials, the proper range can be determined. For a 500 foot-per-second aircraft, the limit of the red range should be at point 1 or about 9,500 feet or 1.58 nautical miles, if the maximum sustained climbing angle is 7.5 degrees. The maximum sustained climb angle of a given aircraft varies with several factors; in general, it increases with faster aircraft. A conservative value should be used here to allow a margin of safety. If an aircraft is already climbing

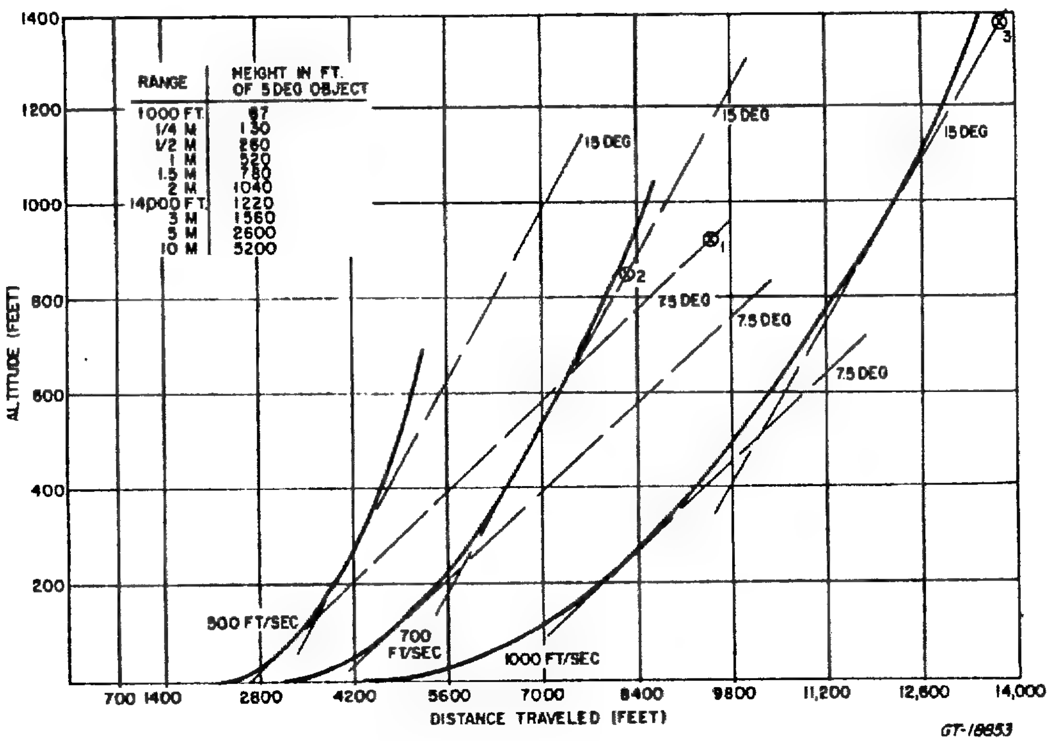

Figure B-3. 1-G Pull-Up Curves

at some angle when the need to climb over an obstacle of maximum height above the flight path arises, this climb angle is then referenced to the previous climb angle, and the true climb angle is the sum of the two. For a 700-foot-per-second aircraft, the limit of the red range should be at point 2, or about 8300 feet or 1.4 miles for a maximum sustained climb angle of 15 degrees. For a 1000-foot-per-second aircraft, the red range limit should be at point 3 or about 2.3 miles, if the maximum sustained climb angle is 15 degrees. It should be noted that the 2-g pull-up curve for a 1000-foot-per-second aircraft is almost identical with the 1-g curve for a 700-foot-per-second aircraft. Thus a red range limit of 1.5 miles is adequate for: a 500-foot-per-second (or 300-knot) aircraft using a 1-g pull-up and maximum sustained climb angle of 7.5 degrees; a 700-foot-per-second (or 420-knot) aircraft using a 1-g pull-up and maximum sustained climb angle of 15 degrees; and a 1000-foot-per-second (or 600-knot) aircraft using a 2-g pull-up and 15-degree maximum sustained climb angle. This is the nominal red range limit used in the system, but it can be varied from 0.5 to 2.5 miles.

This radar set has a minimum range of 0.25 mile. If a path 150 feet above a flat terrain is to be flown, the terrain will be 5 degrees below the aircraft heading and at a range of 1700 feet when it disappears from the bottom of the image. This is 200 feet before it would disappear if it were to fall within the minimum range. Thus the minimum range is not a limitation, if a clearance of 150 feet is flown.

The yellow range extends from 1.5 to 3 nautical miles. It appeared desirable to make the yellow range interval short, to increase its signal-to-noise ratio and consequent reliability. The green range may extend from 3 to 10 or 20 nautical miles, depending on the range switch setting. It is believed that the green range will be used more as a short range navigation aid in selecting a desired approach and that the yellow range will be where the actual avoidance maneuvers are performed.

Because of the nature of the targets and the near grazing angles involved in terrain avoidance, the return signals will be small. In addition, the C-scope presentation (in color in this system), where noise is integrated over a long time or range interval, requires a better signal-to-noise ratio than a radar system using narrow range gates. Using the low frame rates required to allow adequate sector coverage and beamwidth, there is little, if any, scan-to-scan integrations on the display. The small number of hits per scan required to allow adequate sector coverage and beamwidth permit little pulse-to-pulse integration on the display. The result is that the smallest usable signal must be enough above the noise level to allow the noise to be gated out. Under these conditions, the maximum signal-to-noise ratio is realized when the energy per pulse or the product of pulse width and peak pulse power is maximum. This is in contrast to a radar set where many pulses are integrated in the display with the result of maximum effective signal-to-noise ratio being achieved when the average power is maximum. Thus for maximum range, the maximum pulse width which the magnetron is designed for should be used. On the other hand, for maximum sector coverage and frame rate, the prf should be maximum. These two requirements are incompatible, since their product is limited by the maximum rating of the magnetron.

The two highest power magnetrons available for K_a-band are the MA-207 and the 6799. The MA-207 has a nominal pulse power of 60 kw, a pulse width of 0.25 microsecond, and a duty factor of 0.0004. The 6799 has a nominal pulse power of 150 kw, a pulse width of 0.1 microsecond, and a duty factor of 0.0002. The relative range of these magnetrons in this system, where each

return is required to exceed the noise level, may be expressed as:

$$\frac{R_{(6799)}}{R_{(MA-207)}} = \sqrt[4]{\frac{P_{p(6799)}\ PW_{(6799)}}{P_{p(MA-207)}\ PW_{(MA-207)}}} = \frac{150\ \text{KW} \times 0.1\ \mu\text{sec}}{60\ \text{KW} \times 0.25\ \mu\text{sec}} = 1 \text{ for point targets.}$$

The expression under the radical represents the ratio of the power per pulse. In a radar system where integration is accomplished in the display, the ratio of the average power would give the relative range. This is equivalent to including the ratio of the prf under the radical as a multiplier. Thus under optimum operating conditions, the maximum range for point targets is equal for the two magnetrons.

For area targets,

$$\frac{R_{(MA-207)}}{R_{(6799)}} = \sqrt[4]{\frac{P_{p(MA-207)}\ PW_{(MA-207)}\ A207}{P_{p(6799)}\ PW_{(6799)}\ A(6799)}}$$

where A represents the effective target area.

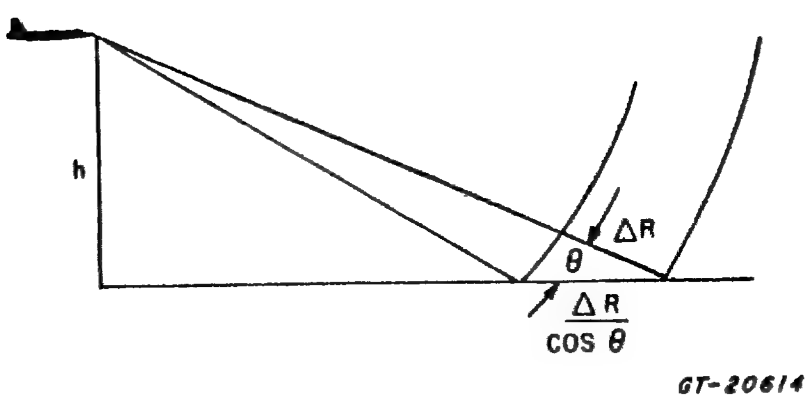

Figure B-4. Target Illuminated at an Angle

Where an area target is illuminated at an angle as in figure B-4, returns are received simultaneously from a range segment

$$\Delta R = \frac{1}{2}\ C\ PW,$$

where C = velocity of propagation. The actual target area which is effective in producing the instantaneous signal return has a length $\frac{\Delta R}{\cos\theta}$. The area is approximately a rectangle for a narrow antenna beamwidth (BW) and has a width equal to RBW.

Then,

$$\text{area} = (\text{RBW})\left(\frac{\Delta R}{\cos\theta}\right) = (\text{RBW})\,\frac{C\ \text{PW}}{2\ \cos\theta}$$

and

$$\frac{\text{Area (MA-207)}}{\text{Area (6799)}} = \frac{R_{(\text{MA-207})}\ \text{PW}_{(\text{MA-207})}}{R_{(6799)}\ \text{PW}_{(6799)}}$$, after eliminating constants.

Substituting this value of A into the relative range equation above,

$$\frac{R_{(\text{MA-207})}}{R_{(6799)}} = \sqrt[3]{\frac{P_{p(\text{MA-207})}\ \left[\text{PW}_{(\text{MA-207})}\right]^2}{P_{p(6799)}\ \left[\text{PW}_{(6799)}\right]^2}}$$ for area targets.

Substituting values:

$$\frac{R_{(\text{MA-207})}}{R_{(6799)}} = \sqrt[3]{\frac{60 \times .25^2}{150 \times .1^2}} = 1.35$$

Thus, it is shown that for area targets the MA-207 has greater range.

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APPENDIX C.

REPRINT OF INSTRUCTION MANUAL FOR

RADAR TERRAIN CLEARANCE SET AN/APQ-82 (XY-1)

This appendix is an exact reprint (including page numbers) of the Instruction Book for the Radar Terrain Clearance Set AN/APQ-82 (XY-1), dated November 1958.

CONFIDENTIAL

Instruction Manual

RADAR TERRAIN CLEARANCE SET AN/APQ-82 (XY-1)

This publication shall not be carried in aircraft on combat missions or when there is a reasonable chance of its falling into the hands of an unfriendly nation, unless specifically authorized by the Operational Commander.

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WESTINGHOUSE ELECTRIC CORPORATION

Air Arm Division **Baltimore, Md.**

2563

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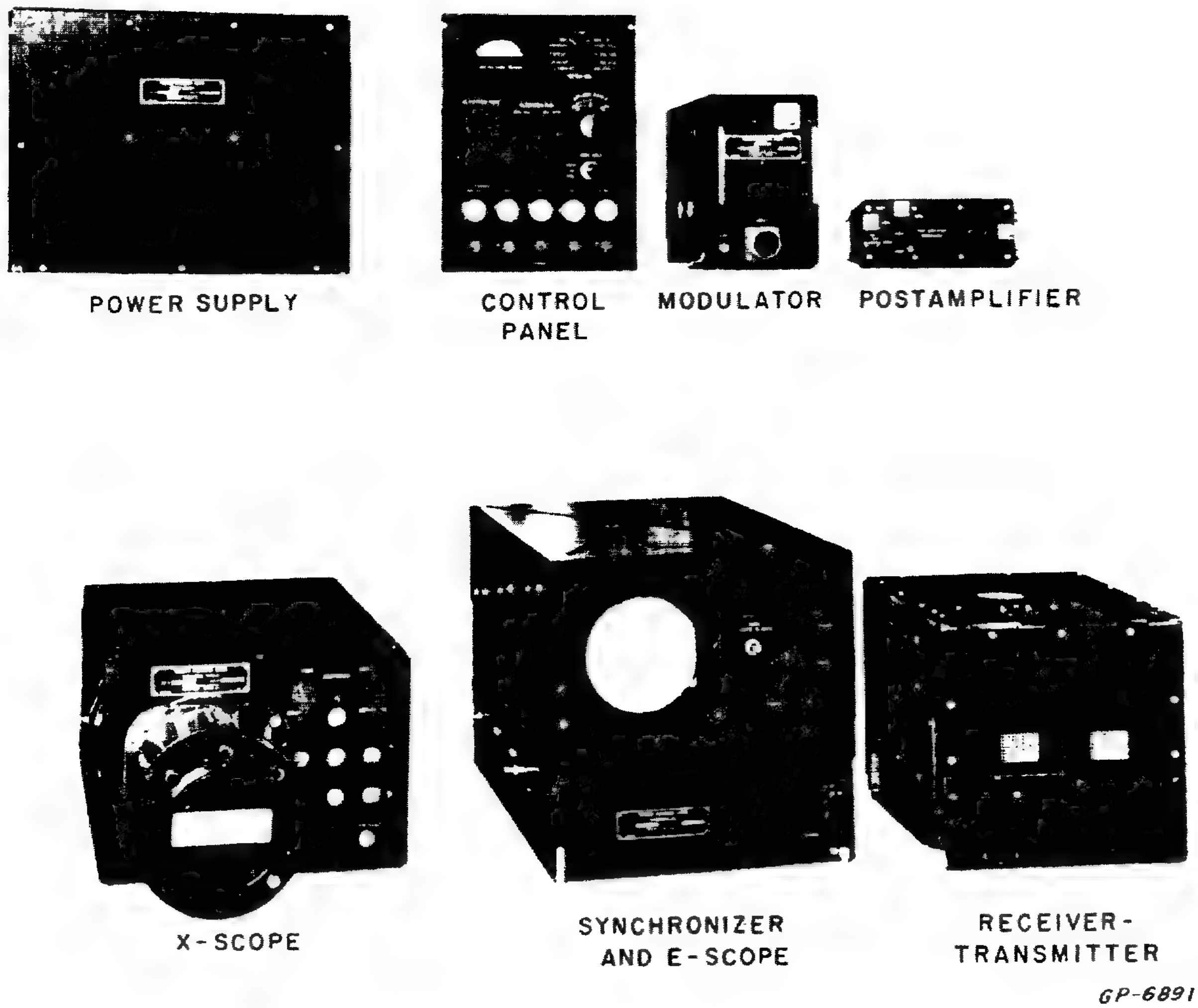

Figure 1-1. Radar Terrain Clearance Set AN/APQ-82 (XY-1), Components (Part 1)

SECTION I

GENERAL DESCRIPTION

1-1. INTRODUCTION

1-2. This manual describes Radar Terrain Clearance Set AN/APQ-82 (XY-1), employed as an aid in low-altitude flight. A sector in space centered about the aircraft's heading is displayed on an X-scope in three dimensions, in what is commonly referred to as a transverse profile. Azimuth and elevation are presented in true perspective, and the third dimension, depth or range, is displayed as a variation in color. An additional display is available in the E-scope, or profilometer, in which the presentation consists of the range vs elevation profile in the vertical plane of the aircraft's heading. As an added feature, profile planes can be selected at azimuth angles off the aircraft's heading, enabling exploration in detail of terrain on either side. The selected profile is marked by a line on the X-scope to provide for correlation of the two displays.

1-3. EQUIPMENT SUPPLIED

1-4. The equipment supplied and required for operation is shown in figure 1-1 and listed in table 1-1.

TABLE 1-1
EQUIPMENT SUPPLIED

UNIT PER ASSEMBLY	NAME	TYPE DESIGNATION	OVERALL DIMENSIONS			
			LENGTH (in.)	WIDTH (in.)	HEIGHT (in.)	WEIGHT (lbs)
1	Antenna		25	30	17	38
1	Antenna junction box		3	8	10	4
1	Receiver-transmitter		9-3/4	11-1/4	9-1/2	32
1	Modulator		8	10	5-1/4	13

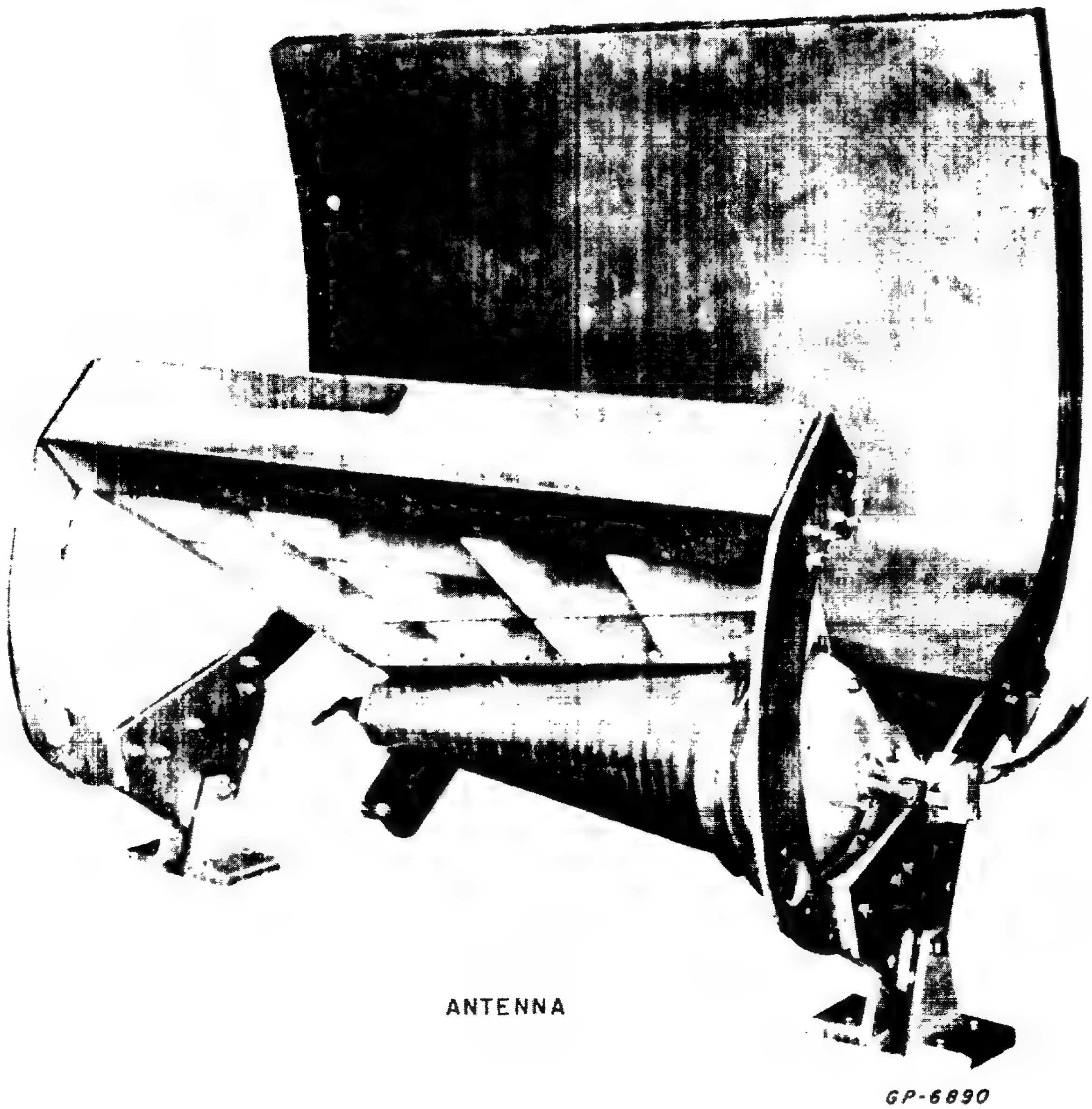

Figure 1-1. Radar Terrain Clearance Set AN/APQ-82 (XY-1), Components (Part 2)

TABLE 1-1 (Continued)

UNIT PER ASSEMBLY	NAME	TYPE DESIGNATION	OVERALL DIMENSIONS LENGTH (in.)	WIDTH (in.)	HEIGHT (in.)	WEIGHT (lb)
1	Postamplifier		7	3	1-1/2	1
1	Synchronizer		18-1/4	12	3-1/2	13
1	E-scope		18-1/4	12	9-1/4	26
2	X-scope		8	27	12	33
1	Power supply		14-7/8	11-3/8	14-3/4	34
1	Control panel		6-3/4	8-1/4	11-5/8	12
1	Set inter-connecting cable					

1-5. GENERAL CHARACTERISTICS

1-6. The following table is a summary of the general operating, electrical, and mechanical characteristics of the Terrain Clearance Radar.

TABLE 1-2

ELECTRICAL AND MECHANICAL CHARACTERISTICS

GENERAL OPERATING CHARACTERISTICS	
Operating altitude	15,000 ft maximum
Operating temperature	-55°C to +55°C (-67°F to +131°F)
Vibration and shock	In accordance with Specification MIL-E-5400
ANTENNA	
Antenna beamwidth	
Vertical	1.75 deg
Horizontal	1.75 deg
Scan sector	
Vertical	10 deg
Horizontal	35 deg
Scan rate	
Vertical	0.75 cps, triangular sweep
Horizontal	21.33 cps, linear sawtooth sweep

TABLE 1-2 (Continued)

TRANSMITTER

Magnetron type	MA-207
Frequency	34,900 ±350 mc
Power	70 kw (nominal)
Pulse width	0.25 microsecond
PRF	1365 pulses per second

RECEIVER

System noise figure	13.0 db
Receiver gain	92 db minimum
Receiver i-f bandwidth	4.5 mc
Klystron type	Varian VA-97
Receiver tuning	Manual or afc
Local-oscillator frequency	45 mc above transmitter
Intermediate frequency	45 mc

RANGE GATE AND SENSITIVITY TIME CONTROL

Range gate	
Minimum range	0.25 ±0.1 nautical mile
Maximum range	10 or 20 nautical miles
STC (sensitivity time control)	Variable amplitude and shape

INDICATOR

Presentation	Azimuth vs elevation in 3 colors to present range segments
Cathode-ray tube type	RCA C73703C storage tube
Marks	Aircraft's heading, horizontal reference

1-7. INPUT REQUIREMENTS

1-8. A summary of the inputs required by the Terrain Clearance Radar follows:

115 volts, 400 cps, 3 phase, Y-connected at 7.5 amp

28 volts dc at 2.7 amp

Aircraft's vertical reference, 2 synchro inputs

Hydraulic fluid at 1000 psi and 0.5 gpm

Air pressure 40 psig.

SECTION II

PRINCIPLES OF OPERATION

2-1. SYSTEM OPERATION

2-2. For purposes of daylight viewing, high brightness is required of the cathode-ray tube used in the X-scope. Similarly, the slow frame rates employed in terrain avoidance systems make high image persistence mandatory. These two characteristics are combined in the storage-type tube used in this system. The present storage tube has a very limited dynamic range, there being about a 3-volt grid swing from black to an overdriven condition in which the spot is blooming. This is an admitted shortcoming of the storage-type tube which the manufacturers are working on, and they expect to see improvement within the next year. Because of the limited grid swing, very little ripple can be tolerated on the X-scope 2000-volt supply or on the output of the driving amplifiers. For a particular setting of the brightness controls, if this ripple is as much as 1 volt, either the display will be limited to the video coincident with the crest of this ripple or the image will bloom and cause saturation of the screen. Moreover, the video must be of a constant amplitude to present a display of proper brightness.

2-3. For the red and green display two images are presented on the cathode-ray tube. Color filters are used, and an optical system combines these two images into a single image on the viewing screen. From minimum range to three miles the spot paints a picture on the upper part of the cathode-ray tube. At the time corresponding to three miles range a voltage step is applied to the vertical deflection plate causing the spot to move down and thus start painting the picture on the lower part of the screen. The beam is intensity-modulated, so that the spot is visible only when there is a video return from terrain. To achieve a third color, the beam is turned on so that it is visible at the same point on both images thereby producing their optical combination on the viewing screen. On the X-scope the horizontal

sweep travel during one range sweep is very short, so that turning on the beam during two adjacent time intervals is equivalent to having the spot painted on both images at the same location. This effect is achieved by giving all video pulses a standard width equal to the range interval during which it is desired to present both images and thus present a third color on the viewing screen. This requirement for a standard width, together with the previously described need for constant video amplitude, means that all video presented on the X-scope can be identical and can be generated by a pulse generating circuit which is triggered by the actual video. This standardized video is made 18 microseconds or 1.5 nautical miles wide. Thus any return from terrain at a range between 1.5 and 3 miles starts during the painting of the red image and lasts into the painting of the green image, achieving the desired third color. The 1.5-mile red range, 1.5- to 3-mile range, and 3-mile to maximum green range are based on considerations of minimum altitude flown, aircraft speed, response time of the pilot-aircraft combination, maximum desired g's in turning, and maximum sustained climb angle. They can and should be changed to suit the conditions in the particular aircraft concerned.

2-4. Since through the use of standardized video all returns and noise appear the same on the X-scope, it is necessary to have a threshold which prevents noise from triggering the standard video generator. Because any video return not above this threshold level cannot be used, this system in effect suffers a range reduction over a system in which actual video is used. Nevertheless, the range of this system is adequate. The postamplifier gain and the bias level of the standard video generator both act as threshold. With receiver bias and STC (sensitivity time control) adjusted to produce nominal video of around 1.5 volts and with an rms noise level of 0.5 volt, the standard video generator bias control can be used to vary the threshold level. Also, a certain amount of threshold effect is obtained by varying the X-scope brightness control. For a correct presentation, it is necessary that only the first video return received from a transmitted pulse be allowed to appear on the screen. The reason, of course, is that if the beam is partially intercepted by a near (or red) object but also strikes a far (or green) obstacle, and both returns are presented, the result appears erroneously as a yellow or intermediate-range object on the viewing screen.

2-5. As previously mentioned, the E-scope presents a vertical profile plane which is normally in the direction of the aircraft's heading but can be rotated 15 degrees to either side. This presentation is caused to appear by gating the video on every time the antenna horizontal scan reaches the desired position. Actual video is used in the E-scope. Since range is the horizontal dimension of the display, the E-scope must be range-gated to provide the 10- or 20-mile maximum range. (A block diagram of the system is shown in figure 2-1.)

2-6. **DETAILED SYSTEM ANALYSIS**

2-7. In the following paragraphs the functioning of each component of the radar set is described. Reference should be made to the block diagram and to the schematics (figures 4-1 through 4-13).

2-8. ANTENNA

2-9. The antenna consists of a sectoral horn feeding a paracyl (parabolic-cylinder) reflector. The entire assembly is rocked mechanically by a hydraulic actuator to achieve the vertical scan. A unique method of folding and rolling up the horn was developed to achieve a rapid sawtooth horizontal scan. The evolution of this rolled-up horn is shown in figure 2-2. To feed the horn a rotary joint was developed which requires no contact between the horn throat and the rotating feed. A pill box is used to direct the energy to the reflector and correct wave-front phasing. For sensing the scan motion and furnishing a pulse to trigger the indicator sweeps a magnetic pickup has been placed in the rotary feed. A three-gang potentiometer is connected to the antenna so that their rotation during the vertical scan furnishes sweep voltages to the indicators. Reversing microswitches, actuated by the antenna, can be adjusted to provide the required 10-degree scan at a suitable vertical position. The horizontal scan sector, since it is determined by the horn configuration, cannot be varied.

2-10. ANTENNA JUNCTION BOX

2-11. The antenna junction box was originally built as a breadboard unit for use in the laboratory with the first developmental model of the antenna. Since the antenna development was terminated at this point, the antenna junction box is included in the system.

2-12. A schematic of the antenna junction box and the associated controls on the antenna scanner is shown in figure 4-1. During each revolution, the

magnetic pickup placed in the antenna rotary feed transmits a pulse to multivibrator V4001. Since the pickup pulse is broad and irregular, if used directly it could cause multiple triggering of the horizontal sweep circuits in the indicator. The multivibrator, with its long recovery time, eliminates this problem. The leading edge of the pulse from V4001 triggers blocking oscillator V4002, which then generates a narrow output pulse suitable for transmission through the coaxial cable to the indicators.

2-13. Upon closure of switch S4004, a triggering pulse is transmitted to blocking oscillator V4003. Triggering pulses occur each time the antenna drive actuator reaches the limit of its stroke. Pulses from V4003 are transmitted to the E-scope, where they are used to initiate the altitude display scan. Switches S4003 and S4004 are positioned to operate at the upper and lower limits of the hydraulic actuator stroke. When one of these switches closes, latching relay K4001 applies to the Moog valve a voltage of proper polarity to reverse the flow of hydraulic fluid to the actuator and thus reverse the scan. The switches should be set to provide a vertical scan of 10 degrees. The Moog valve is of the proportional-control type, having a very fast action in comparison with ordinary solenoid valves. This fast action is gained by use of a low-inductance winding which requires only a small current (3 or 4 milliamperes) to initiate the response. Hydraulic regeneration then supplies the power to complete the response. Under conditions of no electrical input, an adjusting screw on the Moog valve can be used to set the null position of the valve, thus varying the rest position of the antenna about which the scan is performed. Since the limit switches set the limits of the scan, the foregoing adjustment does not affect the scan limits. However, it is used to adjust for equal speed when scanning up and down, thus equalizing the dwell time at the limits. Adjustment of R4022 varies the voltage which is transmitted to the Moog valve and thus controls the scan speed.

2-14. Pressure switch S4001 is operated by atmospheric pressure. It is adjusted to turn off the entire set at an altitude of 15,000 feet, thus protecting it against operation above the maximum altitude for which it was designed.

2-15. RECEIVER-TRANSMITTER

2-16. The receiver-transmitter schematic is shown in figure 4-2. This unit consists of the magnetron, magnetron pulse transformer, filament

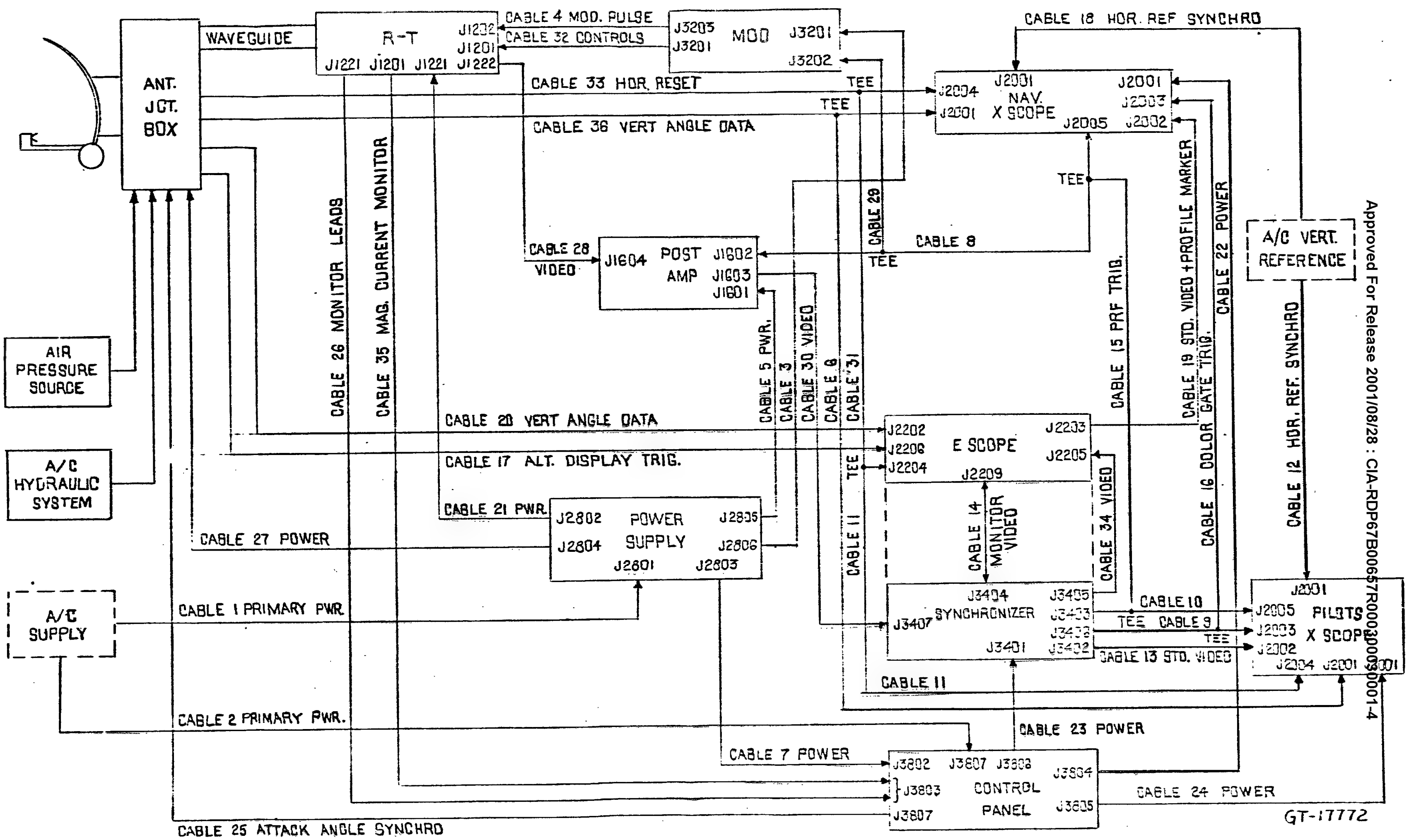

Figure 2-1, Radar Terrain Clearance Set AN/APQ-82 (XY-1), Interconnection, Block Diagram

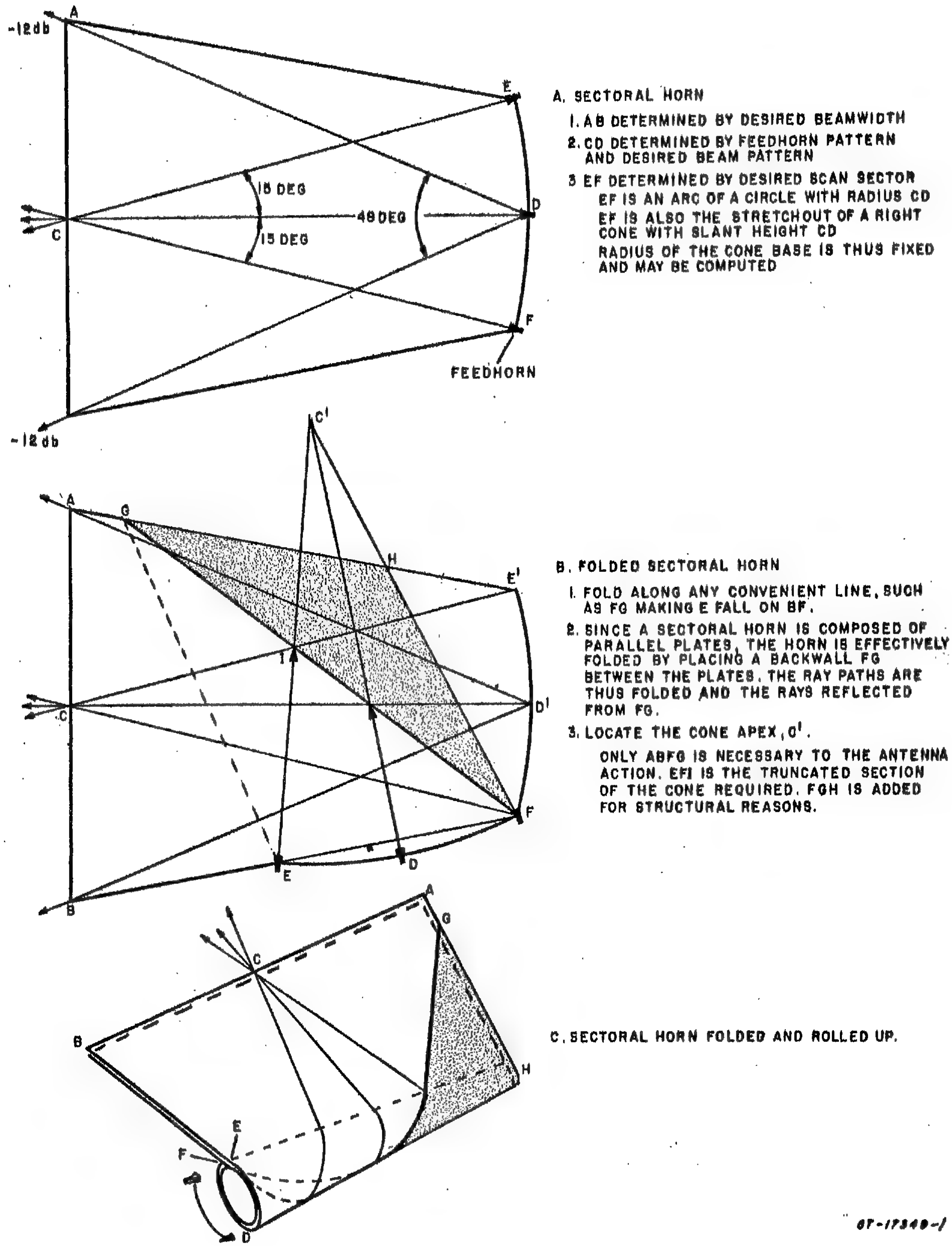

Figure 2–2. Evolution of Folded and Rolled Up Sectoral Feed Horn

supplies, keep-alive power supply, duplexer, radar and afc mixer, afc unit, preamplifier, local oscillator, and filtering and metering circuits.

2-17. Each time the thyratron is fired, a 0.25-microsecond, high-voltage pulse from the modulator is applied to the magnetron pulse transformer, wherein it is stepped up sufficiently to drive the magnetron into oscillation. The r-f pulses from the magnetron are fed to the antenna through a waveguide system, which includes a duplexer and a ferrite isolator. During transmission the TR tube in the duplexer prevents any of the transmitted energy from entering the receiver circuits. Returning signals, blocked from the transmitting circuits by the duplexer ATR tube and the ferrite isolator, are applied to the radar mixer where they are heterodyned with the constant r-f output of the local oscillator. The resulting i-f output is amplified in the i-f preamplifier, and then fed to the i-f output on the receiver-transmitter unit.

2-18. The radar transmitting oscillator is a magnetron tube, type MA207. Pulse transformer T1202 has bifilar windings, so that the high-voltage pulse is equally applied to both sides of the magnetron filament (which is connected to the cathode), thus preventing burnout of the magnetron filament or filament transformer. The average magnetron cathode current should be 5 to 7 ma as indicated by meter M3801 on the control panel, set on MAGX10. Filament voltage for the magnetron is supplied by transformer T1201. In standby operation normal filament voltage is 12.6 volts rms, while in the run condition only 8.0 volts rms is needed for proper magnetron operation.

2-19. The r-f transmission lines are hollow, rectangular waveguides, type RG-96/U, made of coin silver to decrease losses. They are used to interconnect the magnetron, ferrite isolator, duplexer, and antenna as well as the local oscillator, receiver mixer, afc take-off, and afc mixer. The r-f plumbing contains attenuators E1251, E1253, E1256, and E1257; "rat race" E1254, directional coupler E1265, termination E1264, magnetron sample take-off E1259, and ferrite isolator E1266. E1257 determines the amplitude of the transmitted-pulse sample that is coupled to the afc balanced mixer Z1801. E1253 fixes the signal level of the local-oscillator output applied to "rat race" E1254. The low-power termination, E1264, closes the unused arm of E1254. The rate race provides isolation between radar mixer Z1404 and afc mixer Z1801, and the division of power between these two mixers is controlled

by E1251 and E1256. The portion of the waveguide connecting the magnetron through the duplexer to the antenna is pressurized at 32 to 42 psi; a pressure interlock switch is connected to E1259.

2–20. V1222, the TR tube, receives its keep-alive voltage through dropping resistors R1221 and R1222 from molded unit Z1221, a nonregulated power supply rated at 1000 volts, no load.

2–21. The output of local oscillator V1223, which is a type VA-97 klystron, is combined in the radar balanced mixer with the received echo signals to produce the radar intermediate frequency. It is also coupled to the afc balanced mixer, where it is heterodyned with a small sampling of each transmitted pulse to produce afc i-f signals. These signals are used to compensate for any drift in the magnetron frequency or the local-oscillator frequency, and in so doing they maintain correct frequency inputs to the receiver.

2–22. R–F MIXER AND PREAMPLIFIER. The preamplifier schematic is shown in figure 4-3. The balanced mixer, Z1404, is of the rat-race type and is mounted directly on the preamplifier chassis. The mixer has two waveguide inputs, consisting of the local-oscillator signal and the returning signals through the antenna and duplexer. To obtain the desired 45-megacycle intermediate frequency the two inputs are beat together by means of the matched, reversible pair of crystals, CR1401 and CR1402. Each crystal current is filtered and can be monitored by the meter on the control panel.

2–23. The signal is coupled to the grid of V1401 by means of T1401, a doubled-tuned, transitionally coupled transformer, designed to step up the i-f impedance of the crystal to the optimim level for noise figure, as determined by the type 5718 input triode, V1401.

2–24. V1401 and V1402 make up the low-noise cascode circuit, the former being capacitance-neutralized by C1409. T1402 is a trifilar interstage transformer with near-unity coupling, and T1403 and T1404 are bifilar interstage transformers with unity coupling. T1405 is a bifilar step-down transformer that works into the 91-ohm impedance of the coaxial cable between the preamplifier and postamplifier.

2–25. The preamplifier has an overall gain of approximately 54 db and a bandwidth of 5.5 mc.

2-26. AUTOMATIC FREQUENCY CONTROL (AFC). The afc schematic is shown in figure 4-4. The afc chassis consists of a balanced mixer, three pentode (5840) stages of i-f amplification, a duo-triode (6112) discriminator, a differential amplifier (6111), video amplifier (6111), and a diode phantastron control circuit (5784). The afc provides an automatic adjustment of the repeller voltage of the klystron, with the result that the frequency of the klystron is held at 45 mc above the magnetron frequency.

2-27. During afc operation, a small sample of each transmitted pulse is coupled out of a small opening in the waveguide, further attenuated by E1257, and applied to afc balanced mixer Z1801. In the mixer this sample signal pulse is heterodyned with the local-oscillator signal, and the resultant 45-mc pulsed i-f signal is coupled by input transformer T1801 to the grid of V1801, the input stage of the afc i-f amplifier. The afc i-f signal is passed through a conventional, staggered, triple amplifier consisting of V1801, V1802, and V1803, and is then coupled by transformer T1804 to a Weiss discriminator with triode detectors. Positive-going signals on the grids are detected, and the resulting negative pulses on the plates are coupled to the differential amplifier with two sections in parallel. The output of V1806 is capacitance-coupled to the biasing network of C1813, CR1803, and R1817. For positive input pulses the output is a negative voltage proportional to the amplitude of the input pulses. When this negative voltage is in the order of 6 volts, V1807 stops sweeping and functions as a d-c amplifier, with its output coupled through R1819 to the repeller of the local oscillator. This completes the afc loop.

2-28. The afc crystal currents, which should have a value of 0.1 ma, can be monitored at the control box.

2-29. MODULATOR

2-30. The modulator schematic is shown in figure 4-5. This unit contains the high-voltage power supply, discharge thyratron V3201, pulse-forming network Z3201, thyratron trigger circuit, and high-voltage overload circuit. These circuits develop high-voltage pulses for application to magnetron V1201 through pulse transformer T1202 in the r-f head of the receiver-transmitter unit.

2-31. When the OFF-STBY-RUN switch on the control panel is positioned at RUN, 115-volt, 400-cps, 3-phase power is applied to the primary of T3201 in

the modulator high-voltage power supply. This power supply is protected by overload relay K3202, which has a potentiometer across its coil to give trip-current adjustment. The output from bridge rectifier CR3201 through CR3230 is applied through charging choke L3201 to pulse forming network Z3201, which is resonant at approximately 1365 cps. The charge path is completed through the primary of pulse transformer T1202 in the receiver-transmitter unit. The 30-volt pulse input at J3202 is amplified by V3203 and then applied to the plate of blocking oscillator V3202, whose 225-volt trigger output at 1365 pps is applied to the grid of discharge thyratron V3201. When the thyratron fires, it short-circuits the pulse-forming network, thus causing a high-amplitude pulse of current to flow through the primary of pulse transformer T1202. The pulse has a duration of 0.25 microsecond and it develops 3.4 kv across the primary of T1202 in the receiver-transmitter unit. During the discharge time of the pulse forming network, charging choke L3201 presents a high impedance to the surge current, thereby isolating and protecting the modulator high-voltage supply. Oscillations are prevented from occurring during the discharge of pulse forming network Z3201 by the inverse diode CR3231 through CR3240.

2-32. Premature operation of modulator thyratron V3201 is prevented by means of a 5-minute delay relay, which retards application of high voltage until completion of warmup.

2-33. POSTAMPLIFIER AND SENSITIVITY TIME CONTROL (STC)

2-34. The postamplifier consists of four pentode (6205) i-f stages, a second detector, and a duo-triode (6111). One half of the duo-triode is a cathode-follower output stage and the other half is the STC control tube. The schematic is shown in figure 4-6. The i-f interstage transformers are bifilar and unity-coupled, in Cambridge shielded forms.

2-35. When the bias control is set for maximum gain, the postamplifier section has a gain of 38 db minimum, a minimum bandwidth of 6 megacycles, and a maximum rise time of 0.12 microsecond.

2-36. The i-f input cable from the preamplifier is terminated by 91-ohm resistor R1601. The i-f amplifier consists of two staggered pairs. V1602 and V1603 are gain-controlled at their grids by an adjustable bias and an adjustable sensitivity time control (STC) signal that is superimposed upon the bias. The second detector is a silicon crystal, CR1601.

2-37. The video output from the second detector is coupled to the cathode-follower output stage, V1605A, which is impedance-matched to the 91-ohm coaxial cable terminated in the synchronizer chassis.

2-38. The STC wave, generated from a positive, 30-volt, 1-microsecond trigger pulse at the pulse repetition frequency, enters the postamplifier on J1602. R1620 adjusts the amplitude of the STC signal applied to the grids of V1602 and V1603, while R1621 adjusts the waveshape. R1622 is the bias control.

2-39. SYNCHRONIZER

2-40. The synchronizer provides the timed pulses necessary to correlate and synchronize the various functions of the Terrain Clearance Radar. A block diagram of the entire synchronizer showing how the individual sections are combined is shown in figure 2-3.

2-41. This unit employs a transistorized crystal-controlled oscillator (operating at 81.94 kc ±0.012 percent) to trigger blocking oscillator Q601, whose output provides markers spaced one nautical mile apart and also furnishes a trigger to the succeeding transistorized binary stages.

2-42. Reference to figure 2-4 will indicate the combinations of binary stages (designed with inhibitor feedback) which provide the necessary count-down sequences to obtain a pretrigger pulse. The pulse frequency is one-sixtieth of the oscillator frequency, or 1365 pulses per second. Figure 2-5 demonstrates the time sequence of waveforms within the logic circuits illustrated in figure 2-4. These waveforms are taken from the collectors of the various transistors incorporated in the logic circuits.

2-43. Figure 2-6 is a sectional block diagram indicating delay functions and trigger pulse outputs to other units of the system.

2-44. Figure 2-7 illustrates the delay and gating operations.

2-45. Figure 2-8 is a block diagram of the video amplifiers and standard video generator section.

2-46. As shown in figure 2-6, the pretrigger pulse passes through inverter V609A and is then used to trigger both the prf marker phasing multivibrator and the range-gate marker phasing multivibrator. The former multivibrator determines the phase relationship between the repetition-rate pulse output from prf blocking oscillator V611 and the occurrence of the range-marker pulses displayed on the E-scope.

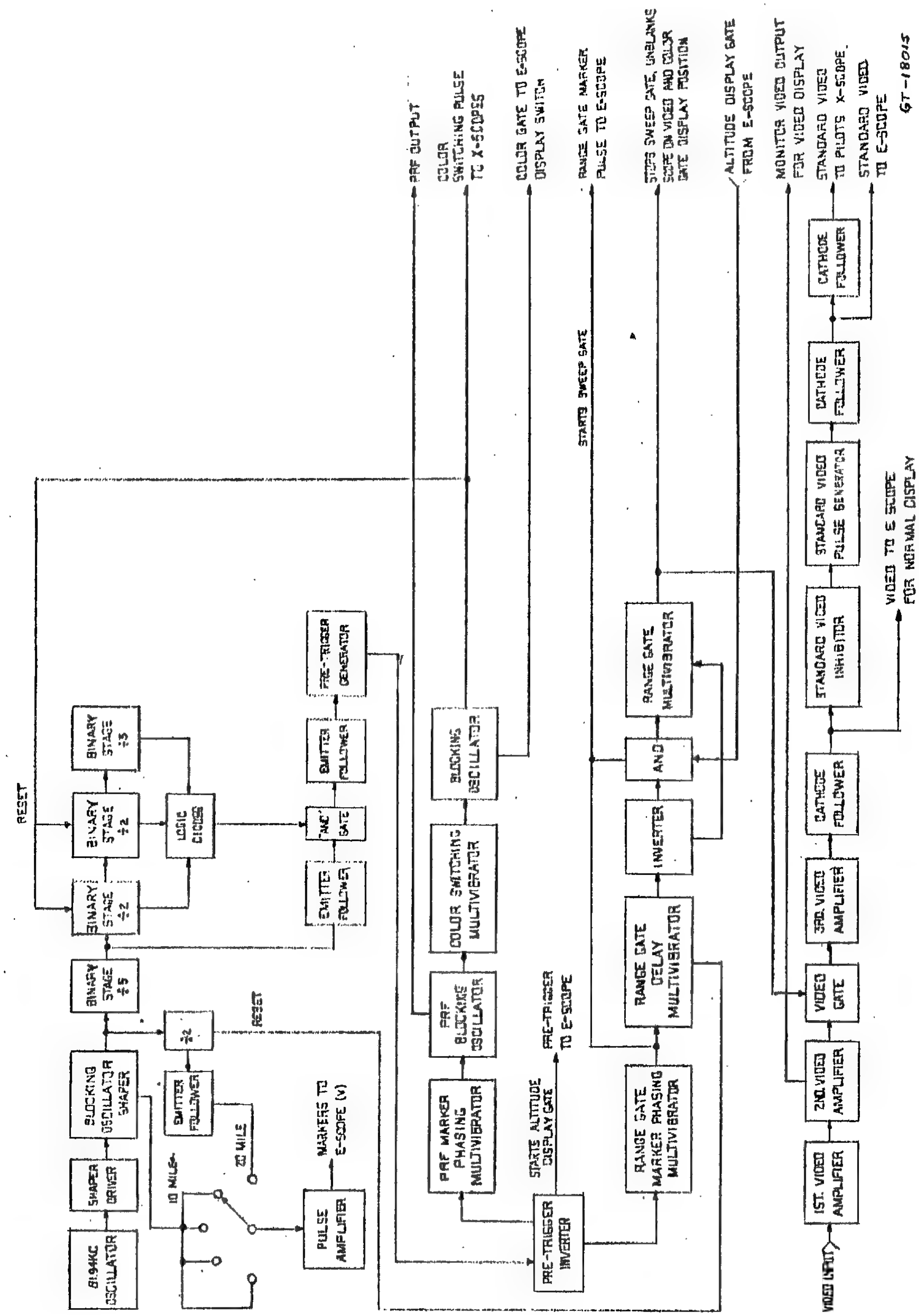

Figure 2–3. Synchronizer Block Diagram

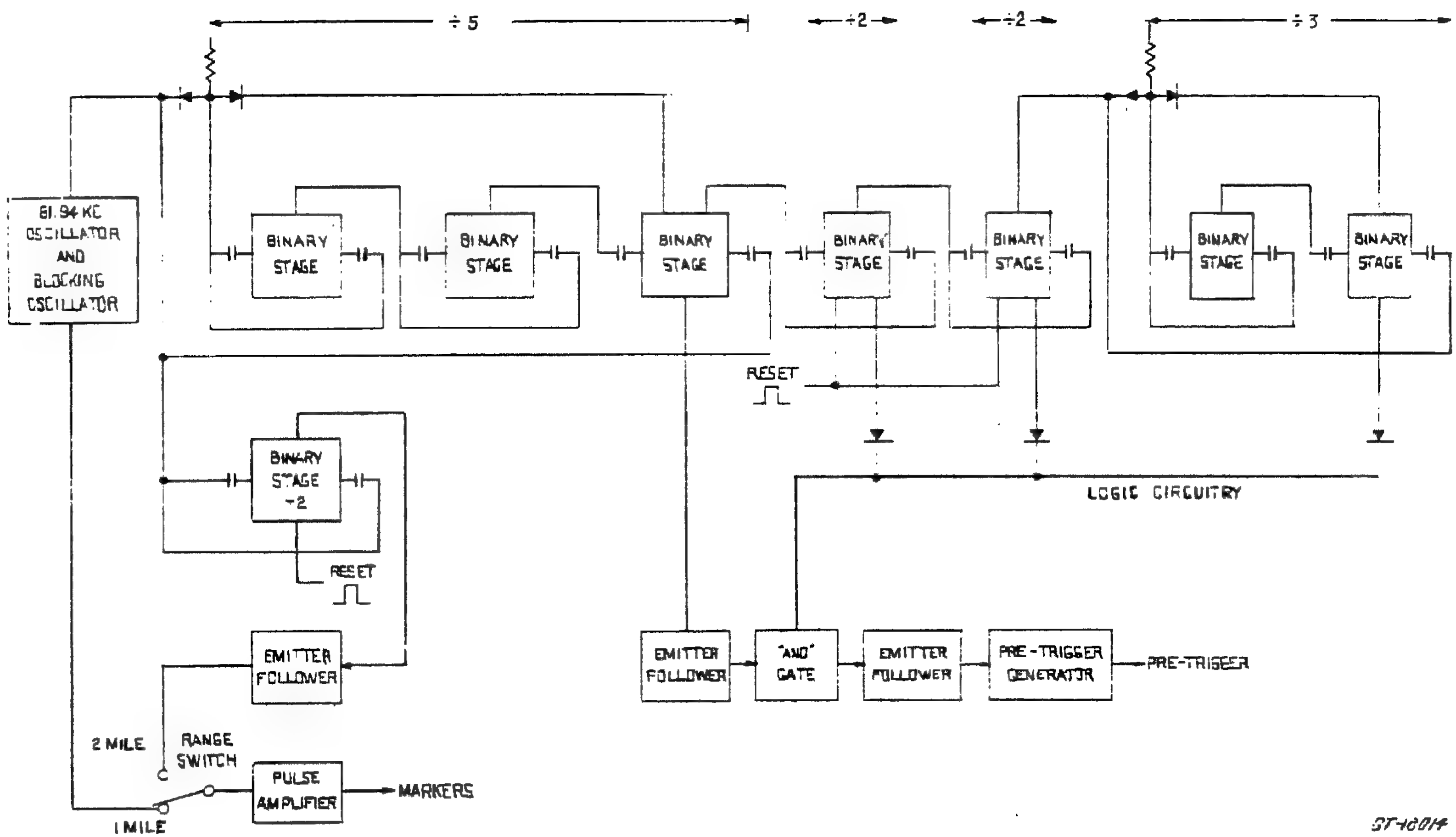

Figure 2—4. Synchronizer Count Down Circuit, Block Diagram

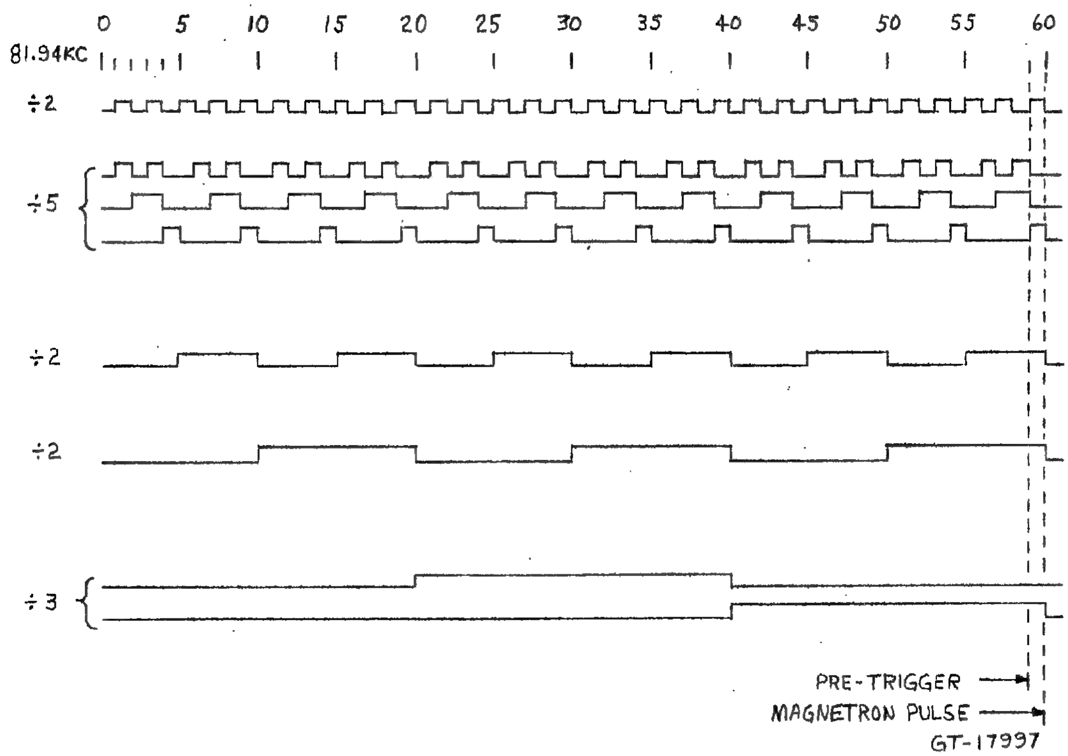

Figure 2-5. Timing Pulse Output, Synchronizer Count Down Circuit

2-47. The color-switching time multivibrator, V612, is triggered by prf pulses from blocking oscillator V611. This circuit determines the necessary delay before triggering the color-switching time blocking oscillator, V613. Pulses from V613 are used to change display positions on the X-scopes so as to produce the separate range-indicating colors.

2-48. Phase relationships between the range gate and the marker pulses are determined by range-gate marker phasing multivibrator V614. This multivibrator also starts the sweep gate in the E-scope.

2-49. Range gate delay multivibrator V615 determines the time interval between the leading edge of the magnetron output pulse and the start of the range-gate generator, V617. In this circuit strong echoes from close-range targets are prevented from triggering the standard video circuits, as the range gate is used to time the video input at video gate V603 (figure 2-8).

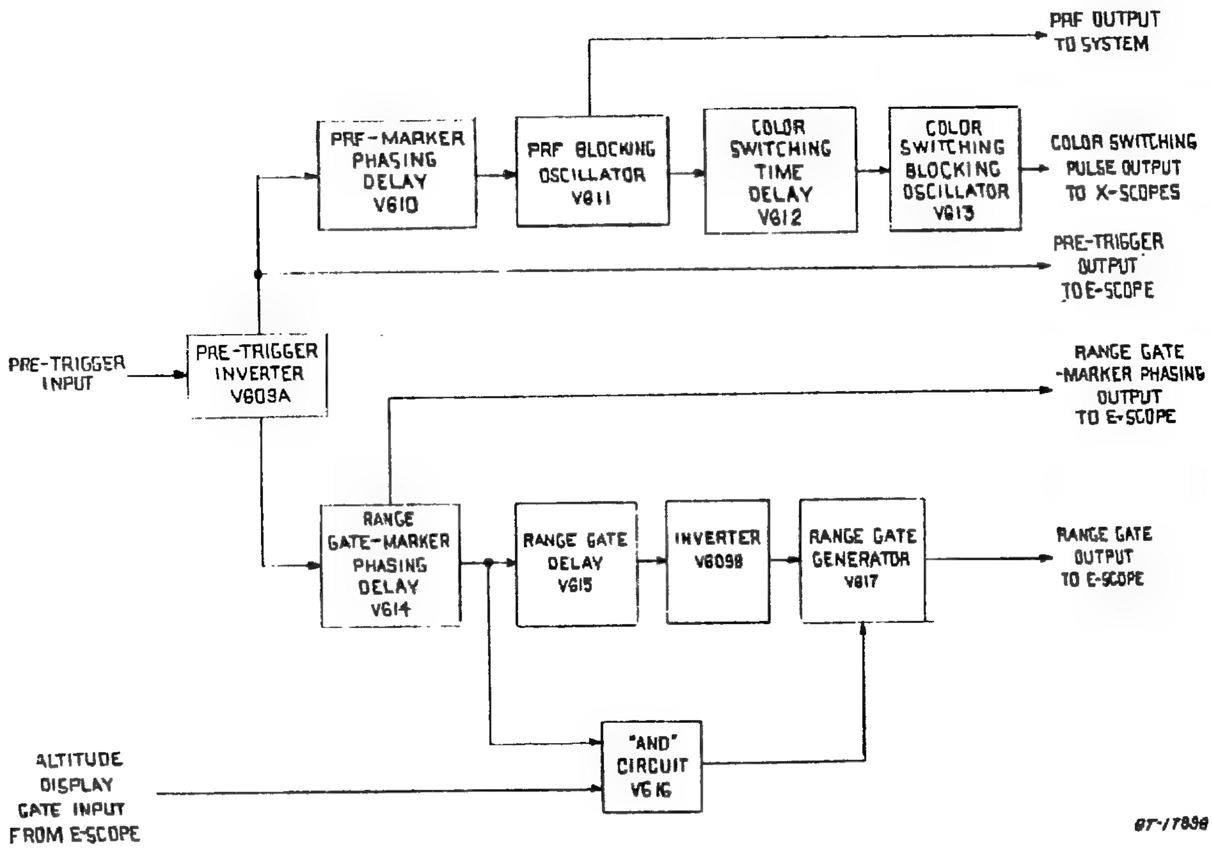

Figure 2-6. Synchronizer Delay Function Circuits, Block Diagram

2-50. The "And" circuit of V616 is a coincidence amplifier, whose function is to trigger range gate generator V617. Triggers are supplied whenever an altitude display gate from the E-scope coincides with the end of the range-gate-marker phasing delay. By this method the range-gate delay interval is bypassed and the range gate starts at the same time as the magnetron pulse, so that all video returns occurring immediately after the magnetron pulse can be presented on the altitude display portion of the E-scope.

2-51. Range gate generator V617 can also be triggered by the range gate delay, V615. As explained previously, the range gate controls the time during which video is permitted to trigger standard video generator V606 (see figure 2-8). It is further used to stop the sweep gates in the E-scope unit.

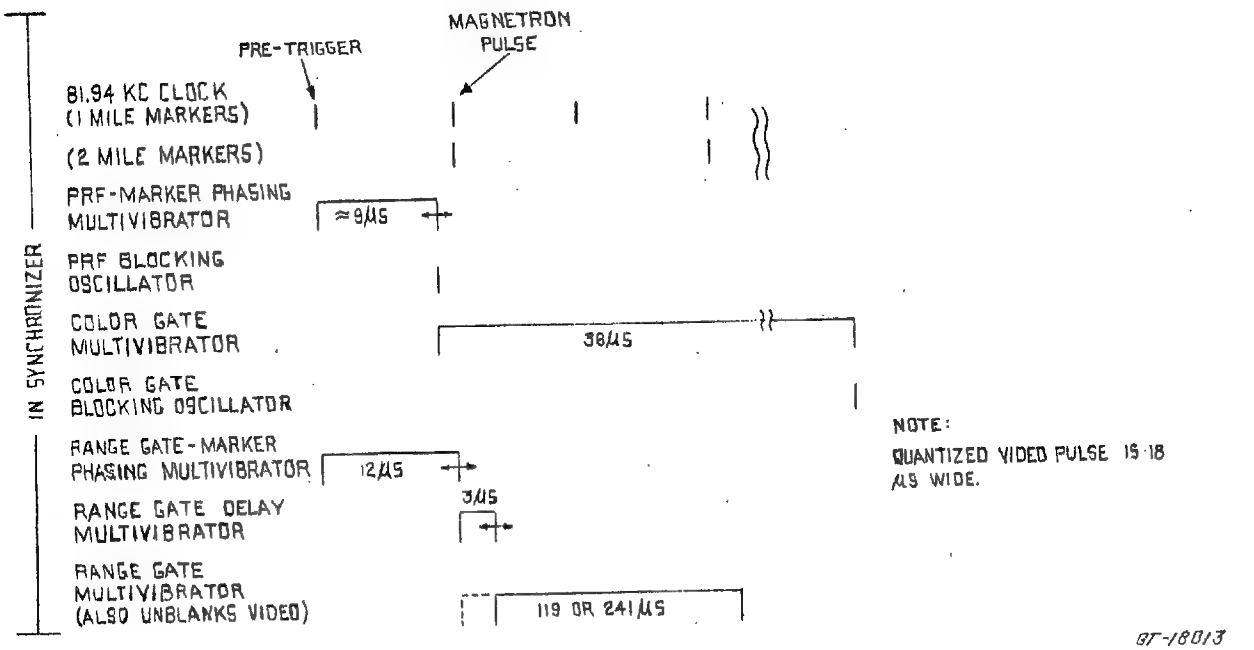

Figure 2-7. Synchronizer Delay Function, Pulse Timing Diagram

2-52. The RANGE switch is employed to (a) change the delay time of the range gate multivibrator, (b) change the gain of the horizontal sweep for the E-scope, (c) select one-mile markers for the 10-mile range and two-mile markers for the 20-mile range, (d) change the gain of the vertical sweep in the E-scope, and (e) control the range displayed on the X-scope.

2-53. Figure 2-8 shows the video circuits. The first and second stages, V601 and V602, amplify the input video by 10 for application to the E-scope through monitor video output jack J3404. The amplified signal is also passed through threshold control R3405 to video gate tube V603, which is activated upon arrival of the range gate. The video signals (minus noise which was removed at the threshold control) are then passed to the third video amplifier, V604. Cathode follower V605 transmits the video pulses to standard video inhibitor V608 and also to the E-scope for use in the normal display.

2-54. The standard video generator, V606, is a delay multivibrator. An 18-microsecond output pulse (equivalent to 1.5 nautical miles) is produced

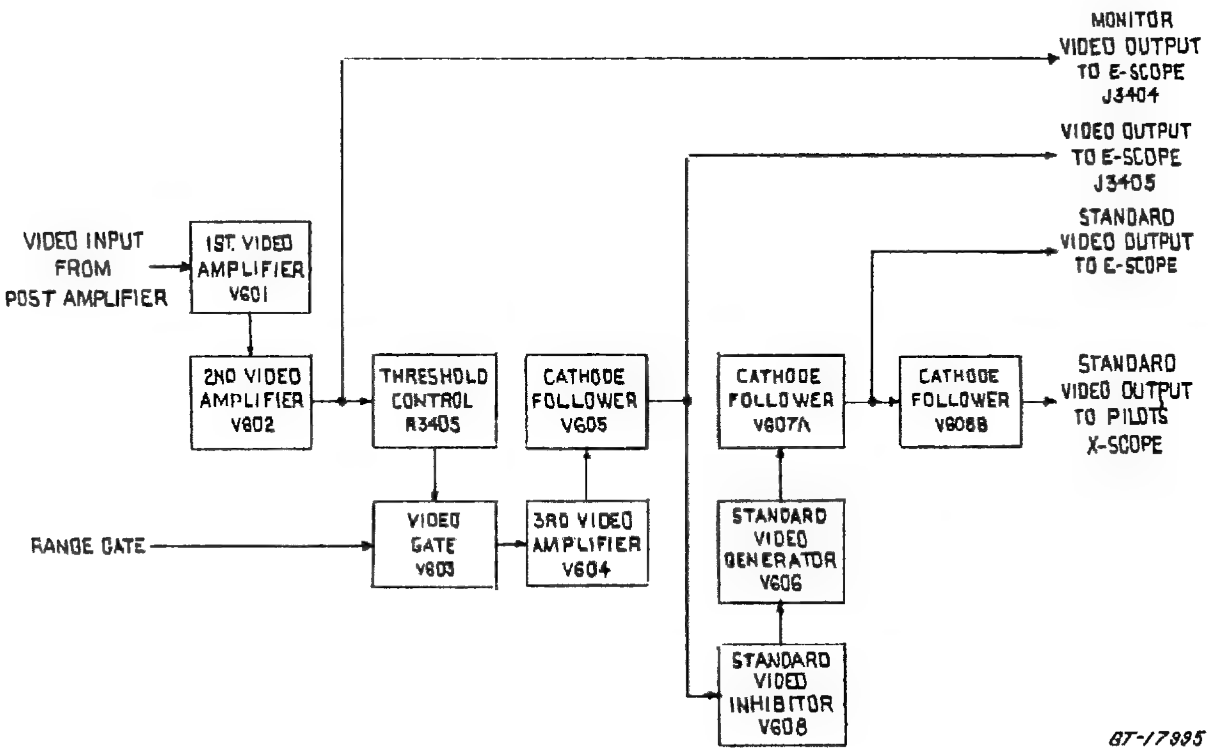

Figure 2-8. Synchronizer Video Circuits, Block Diagram

each time this circuit is triggered by a pulse from standard video inhibitor V608. The delay of the standard video inhibitor multivibrator is adjusted to be greater than the 244 microseconds equivalent to the longer or 20-mile range. As a result, the standard video generator can be triggered but once during each range period, a condition to be desired since otherwise a target echo appearing in the short or red range could combine with one appearing in the long or green range during the same range interval and thus produce a combined or yellow target on the X-scopes. The range information would then be incorrect, since a red target would be made to appear as if it were farther away, i.e., in the yellow range.

2-55. Cathode follower V607A passes the standard video to the E-scope and through cathode follower V607B to the pilot's X-scope.

2-56. E-SCOPE

2-57. The plug-in type E-scope unit mounts on top of the synchronizer when a profilometer display is to be added to the system. Figure 2-9 is a block

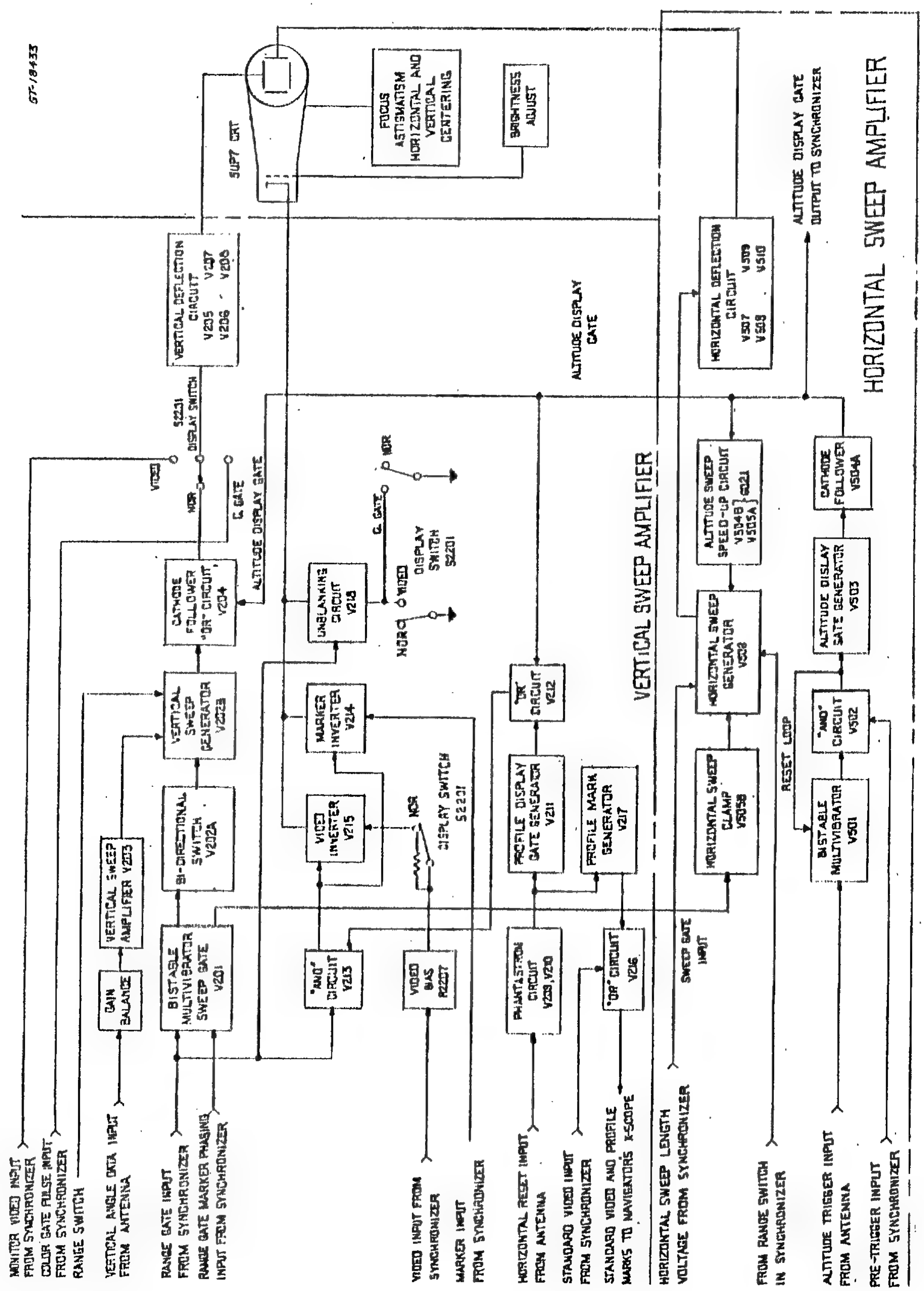

Figure 2–9. E–Scope, Block Diagram

diagram of the E-scope, and figure 2-10 represents a profile display.

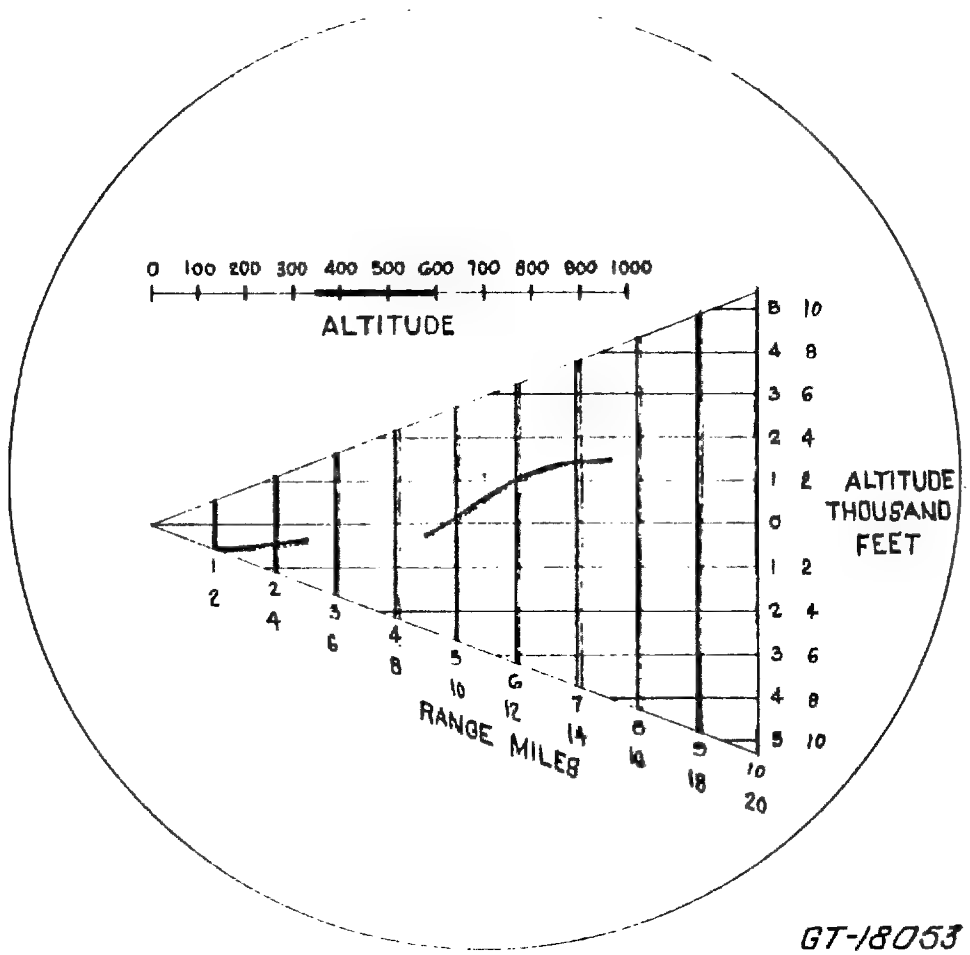

Figure 2-10. E-Scope, Profile Display

2-58. The E-scope chassis contains two plug-in subassemblies, the vertical sweep amplifier and horizontal sweep amplifier. Contained in the main chassis is the 5UP7 cathode-ray tube and necessary high-voltage power supplies and filament transformers. Also incorporated in this housing are a display switch and a profile selector, as well as controls for focus, astigmatism, brightness, horizontal and vertical centering, altitude position, video bias, and vertical angle data.

2-59. In the vertical sweep amplifier section of figure 2-9, it can be seen that the vertical-deflection circuit (V205 through V208) can receive

three input signals, depending upon the setting of the NOR, VIDEO, C. GATE switch. When this switch is in the VIDEO position, a signal is received from monitor video input jack J2209. This signal, originating at the second state of the video amplifier in the synchronizer unit, enables the operator to set the STC shape and amplitude controls and bias controls on the post-amplifier unit.

2-60. When the NOR, VIDEO, C. GATE switch is in the C. GATE (color gate) position, the color gate pulse is displayed on the screen. Under these conditions the operator can adjust the delay of the color switching time multivibrator in the synchronizer. As this multivibrator is the initial source of the color gate pulse, a proper delay in reference to the prf can thus be obtained.

2-61. When the NOR, VIDEO, C. GATE switch is in the NOR (normal) position, linear vertical sweep voltages are applied to the deflection circuit. Development of these voltages is described in paragraphs 2-65, 2-66, and 2-67.

2-62. Bistable multivibrator V201, set by the range-gate-marker phasing pulse from the synchronizer, starts the sweep gate at a time coincident with the magnetron and marker pulses. The range-gate input from the synchronizer resets or stops V201, thus terminating the sweep gate. Application of the sweep gate to bidirectional switch V202A serves to remove the clamping diodes from vertical sweep generator V202B whenever a sweep gate is received.

2-63. Vertical sweep generator V202B is an amplifier incorporating an RC charging path in its grid circuit, the return voltage for which is determined by vertical sweep amplifier V203. The input to the latter circuit is taken from the contact arm of the vertical-angle data potentiometer in the antenna junction box. Since the contact arm is driven by the antenna vertical motion the output of V203 is a modulating voltage for the RC charging path. The result is a sawtooth voltage which rises linearly toward a positive voltage or falls linearly toward a negative voltage, depending upon whether the antenna is tilted up or down from the horizontal position. (See figure 4-1.)

2-64. The output of V202B is passed to cathode follower "Or" circuit V204 and then to the deflection circuit.

2-65. The horizontal reset pulse from the antenna to J2204, which occurs each time the antenna beam starts from the left side of the scan sector,

triggers phantastron circuit V209 and V210. A variable delay is provided in this circuit which ranges from the beginning of the horizontal sweep to within 200 microseconds of the next horizontal reset pulse. The phantastron output triggers profile display gate V211, which generates a 4600-microsecond gate applied to cathode follower Or circuit V212. Output pulses from the phantastron also trigger profile mark generator V217, thereby producing a 40-microsecond gate which is passed to another cathode follower Or circuit (V216).

2-66. The outputs of the range gate circuit and or Or circuit V212 are connected to And circuit V213. This is a coincidence circuit which provides an output gate equal in width to the range gate whenever both inputs appear simultaneously. The output of the And circuit is used to gate video inverter V215 and marker inverter V214.

2-67. Output pulses from V215 and V214 are used to intensity-modulate the 5UP7 cathode-ray tube. The gain of video inverter V215 is controlled by video bias potentiometer R2207. Whenever NOR, VIDEO, C. GATE switch S2201 is set in the VIDEO or C. GATE position, the video inverter is cut off.

2-68. Unblanking circuit V218 is operative only when S2201 is in the VIDEO or C. GATE position. This circuit produces a negative unblanking gate at the cathode of the E-scope (equal in width to the range gate) that makes the video and color-gate traces visible on the screen.

2-69. The Or circuit of V216 combines standard video signals from the synchronizer unit with the profile mark received from V217 to produce signals for the navigator's X-scope.

2-70. The altitude display gate obtained from the horizontal sweep amplifier subchassis is applied to Or circuits V212 and V204. The latter of these circuits applies this gate to the vertical-deflection circuit, where it is used to move the trace up to the altitude trace line at the proper time. The altitude display gate also causes Or circuit V212 to pass the gate to And circuit V213, where it performs the same circuit functions as previously discussed for the phantastron circuit.

2-71. The horizontal-deflection circuit (V507 through V510) is essentially the same in operation as the vertical-deflection circuit discussed previously. The input signal is received from bootstrap circuit V506, which is held disabled by the horizontal-sweep clamp circuit of V505B until

released by the sweep-gate input signal. V504B and V505A comprise the altitude sweep speed-up circuit, which receives an altitude display gate from cathode follower V504A. The output of this circuit causes the sweep speed of the horizontal sweep generator to increase to approximately 1.25 inches per microsecond during the time that the altitude display gate is received. At the termination of this gate, the sweep speed reverts to the correct value for the range switch setting.

2-72. A trigger from And circuit V502 causes an altitude display gate to be generated in V503 whenever a signal is received from both the pretrigger input and bistable multivibrator V501. This multivibrator is set by the altitude trigger pulse from the antenna unit, and resetting pulses are provided by And circuit V502. Accordingly, the altitude display gate occurs at the pretrigger time, so that all sweeps and gates dependent upon this gate are readied or in position prior to the time they are used.

2-73. X-SCOPE

2-74. The X-scope unit employs a storage-type cathode-ray tube in order to provide the required brilliance and persistence of display.

2-75. The presentation is observed through an optical viewer which converts the display to three colors representing three distinct depths or ranges. An artificial-horizon reticle actuated by the aircraft vertical gyro is also incorporated in the optical unit.

2-76. In addition to the storage tube, the X-scope chassis contains the necessary high-voltage power supplies and filament transformers. It also provides controls for vertical and horizontal centering, video gain, and display separation. Brightness, focus, collimating, and other controls for the viewing and erasing guns of the storage tube are screwdriver adjustments accessible from the front panel.

2-77. Two X-scopes are used in the system, one for the navigator and the other for the pilot. The pilot's X-scope is arranged for mounting behind the instrument panel, with the viewing screen on the optical system approximately flush with the instrument panel. The VIDEO GAIN control is brought out to the instrument panel by means of a flexible shaft, since it is the only control that should be necessary during flight once the other controls are adjusted properly.

2-78. The vertical-deflection circuit for the electrostatically deflected storage tube consists of tubes V1, V4, V5, V6 and V7 (figure 2-11). It is a direct-coupled feedback amplifier with a gain of approximately 10, and its output is fed directly to the deflection plates of the storage tube. V1B, a cathode follower used to provide a centering voltage for the deflection amplifiers, is controlled by the vertical centering knob located on the front panel.

2-79. V1A is a cathode follower which supplies the deflection circuit with the signal information received from the vertical angle-potentiometer in the antenna junction box. Potentiometer R1, in series with this signal circuit, is used to adjust the amplitude of the vertical deflection on the X-scope. V1A also receives a step voltage pulse from the pentode pulse injector, V3. For the duration of this pulse, the vertical-deflection circuit causes a rapid movement of the trace to the upper portion of the X-scope. At the termination of the pulse the trace is returned to the lower portion of the tube. Bistable multivibrator V2 develops the pulse and applies it to pentode pulse injector V3. Pulses begin when the prf is received and terminate upon acquisition of the color gate pulse. Both of these signals originate in the synchronizer. The traces on the upper portion of the X-scope are passed through a red filter to the optical viewer, and traces on the lower portion of the X-scope are passed through a green filter. Consequently, target indications at short range appear in red and those at a greater range in green.

2-80. The horizontal-deflection circuit consisting of tubes V15, V16, V17, V18, and V19, operates in exactly the same manner as the vertical-deflection circuit described previously. V15B is a cathode follower which is used to provide a centering voltage to the direct-coupled deflection circuits. The other half of this tube, V15A, is a cathode follower that couples the output of bootstrap sweep tube V14 to the horizontal-deflection circuit. A linear sawtooth horizontal sweep voltage is provided to the horizontal-deflection circuit by the bootstrap. Potentiometer R92 adjusts the amplitude of the horizontal-deflection on the X-scope.

2-81. Bootstrap reset tube V13 terminates the positive-going sawtooth wave generated by the bootstrap whenever a horizontal reset pulse is received from amplifier V12. This amplifier receives its pulses from the antenna

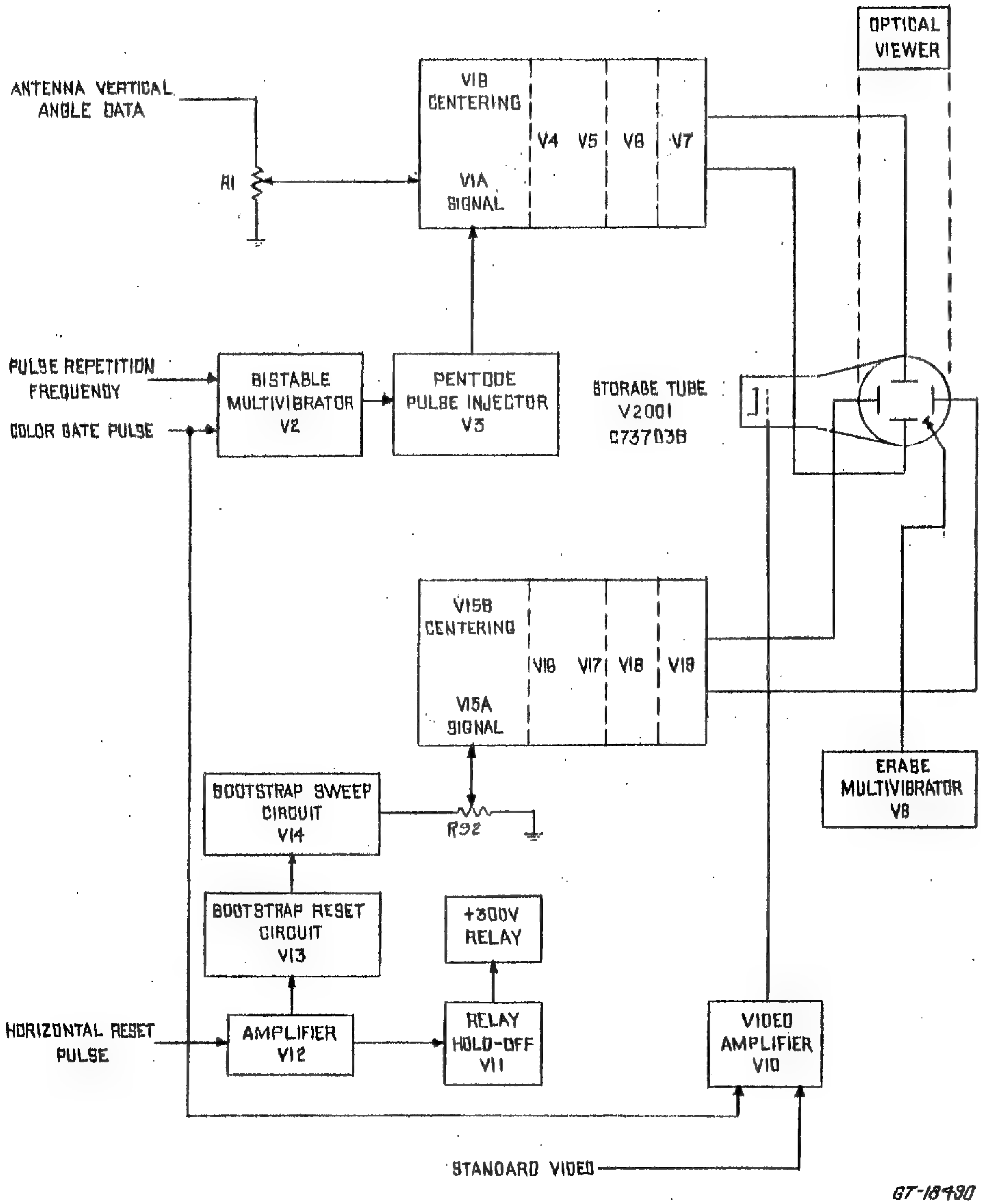

Figure 2–11. X–Scope, Block Diagram

junction unit and passes them to both bootstrap reset tube V13 and relay hold-off tube V11. A 300-volt switching relay (K1) in the plate circuit of V11 is held deenergized as long as horizontal reset pulses are received from the antenna junction box. If these pulses are missing, however, the relay becomes energized and thus removes the positive 300 volts from the storage tube. The tube then ceases writing, and the storage surface is protected from the phenomenon known as runaway charging, which might occur with an undeflected beam.

2-82. Video amplifier V10 receives standard video pulses from either the synchronizer or the E-scope unit and amplifies them sufficiently to drive the writing-gun grid of the storage tube. Another input to V10 is the color gate pulse (from the synchronizer unit), which is used to blank the video amplifier while the X-scope trace is being returned from the upper portion to the lower portion of the tube. By this activity video signals are prevented from being placed on the storage surface during the color switching transition.

2-83. When the X-scope is to be used as a navigator's indicator, the input to V10 is obtained from the E-scope. In the E-scope an additional signal called the profile mark is added to the standard video, in order to enable the navigator to determine which sector of the total field is being displayed on the E-scope.

2-84. The circuit containing V8 is the erase multivibrator, which produces pulses that are applied to the storage-grid backing electrode of the storage tube to maintain continuous erasure of the information stored on the tube. Controls for repetition rate and amplitude are provided for this circuit in order that the degree of erasure may be closely controlled and image persistence regulated.

2-85. POWER SUPPLY

2-86. The power-supply schematic is shown in figure 4-11. Primary voltages to this unit are received directly from the aircraft supply. Standby relay K2801 receives both single-phase and three-phase power through the power-supply fuses. This relay is energized by +28-volts from the control panel, and after a 30-second delay rectifier transformer relay K2802 is energized.

2-87. With the closing of the standby relay, three phase power is supplied to the modulator, receiver-transmitter, and all blowers. Also at this time single-phase power is distributed to all heaters and to the antenna assembly.

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Upon actuation of relay K2802, secondary output voltages are available to the series regulators and their associated control circuits. Simultaneously with the closing of K2802, regulated voltages are available to the system in the following sequence. The -300-volt supply operates immediately and its relay K2804 closes, thereby permitting the -150-volt supply to operate and close K2803. At this time the +400-, +300-, +150-, and 22.5-volt supplies become operable and complete the voltage requirements of the system. As stated above, K2804 is operated by the -300-volt supply, so that the system is protected from loss of bias when the positive voltages are present in the system. The +400-, ±300-, and ±150-volt supplies receive their input voltages from a three-phase silicon rectifier bridge across the Y-connected secondary of transformer T2801.

2-88. The +22.5-volt circuit obtains its input voltage from the +150-volt regulated supply and its output is taken from the cathode of dual triode V2807. The grid bias of this cathode follower is determined by a potentiometer (R2825) in the voltage-divider circuit connected to the -150-volt regulated supply. The regulation of the 22.5-volt circuit for transient pulses is improved by addition of a 2-microfarad capacitor in parallel with the load. Although the d-c regulation is relatively high, it is entirely satisfactory for the present load.

2-89. The +400-volt circuit contains a 6080 dual triode, V2804, used as a cathode follower whose plates are connected to the 490-volt output of bridge rectifier CR2802. Regulation of bias for V2804 is obtained by varying potentiometer R2810 in the voltage divider circuit connected between the plate of V2804 and the +300-volt regulated supply. Voltage regulator tube V2803 is placed in parallel with this grid-bias potentiometer in order to remove the rectifier ripple from the bias circuit. The regulation of the +400-volt circuit is similar to that of the +22.5-volt circuit.

2-90. The +300 and -300-volt circuits differ only in that the positive terminal of the -300-volt supply is grounded.

2-91. Feedback amplifier control of these supplies is effected by four amplifier stages. The first stage is a 6112 triode connected as a differential amplifier. One grid, the feedback grid, obtains error signals from a resistive voltage divider connected across the power-supply output. A 25-turn wire-wound potentiometer incorporated in this voltage divider is

used to set the output voltage level of the supply. The remaining grid of the first stage receives an input or reference signal from a low-temperature-coefficient Zener reference diode (type 1N430A).

2-92. The output of the differential amplifier is direct-coupled to the input of the next stage by means of a Zener diode in order to minimize signal coupling losses.

2-93. The second and third stages are triode-connected 5702 tubes each with Zener-diode coupling in the outputs and Zener diode bias sources in the cathode circuits.

2-94. The last stage is a 6112 dual triode connected as a cascode amplifier. A cascode circuit is used because it permits operating the subminiature tube at a lower plate voltage, thus permitting maximum transconductance and widest dynamic range. The grid of the second half is used to monitor changes in rectifier output voltage due to variations in the a-c supply.

2-95. The output of the last stage in the feedback control circuit is directly connected to the grids of the 6336A dual triode amplifiers, which function as cathode followers between the bridge rectifiers and the load.

2-96. Transient response of the circuit is improved by means of a coupling capacitor connected from the positive terminal of the supply output to the first grid of the cascode stage.

2-97. The d-c open loop gain is approximately 1×10^6 and the transient gain is approximately 400. The overall bandwidth is approximately 400 kc.

2-98. Temperature effects upon the supplies are virtually eliminated by means of individual ovens which entirely enclose the feedback-amplifier control circuits and consequently maintain the circuit components at a temperature of 85 ±2°C.

2-99. The +150 and -150-volt supplies are similar to the 300-volt circuits discussed above, differing only in that the last stages in the control circuits are pentodes rather than cascode-connected triodes. This is feasible because of the lower plate voltages involved. The regulation and ripple of the supplies are as follows:

SUPPLY (volts)	CURRENT (ma)	FULL LOAD RATINGS (%)	
		RIPPLE	REGULATION
+400	50	0.03	±3.8
+300	800	0.025	±0.01
+150	800	0.025	±0.01
+22.5	50	0.3	±3.3
-150	800	0.025	±0.01
-300	200	0.025	±0.01

2-100. CONTROL PANEL

2-101. The 28 volts, dc, and 115 volts, 3 phase, 400 cps for operation of the system are brought from the aircraft supply directly to the control-panel fuses. An altitude limit switch in the antenna assembly interlocks the +28 volts applied to the POWER switch, preventing operation of the system above a preset altitude of 15,000 feet.

2-102. When the POWER switch is at STBY the standby relays apply three-phase and single-phase power to the receiver-transmitter, both X-scopes, the E-scope, and the synchronizer. The standby relays also apply +28 volts to the synchronizer, and both X-scopes, and to the power supply for its standby relay. At the instant the switch is turned to STBY, a 30-second delay relay in the control panel starts its cycle, in order to allow tube heaters to warm up before current is applied to the power-supply voltage windings. At the end of this cycle a holding relay applies +28 volts to the plate relay in the power supply and to a 5-minute delay relay in the control panel. At the close of the 5-minute cycle another holding relay applies +28 volts to a segment of the POWER switch. When the switch is then turned to RUN, +28 volts is applied to the modulator run relay and to the RUN lamp on the control panel.

2-103. The METER SEL switch allows the operator to monitor all d-c supply voltages, the afc and receiver crystal currents, and the magnetron current. In the MAN position the KLYSTRON TUNE switch applies +28 volts to the klystron relay in the receiver-transmitter. The KLYSTRON TUNE potentiometer can be varied manually to change the klystron voltage. When the switch is in the AUTO position, however, the +28 volts is taken off the relay and the potentiometer has no effect on the klystron tuning.

2-104. The MOD OVLD indicator lights when the modulator overload relay operates. When the button is depressed, +28 volts is applied to the overload relay reset coil.

2-105. The ATTACK-ANGLE synchro allows a predetermined setting in degrees to be applied to the vertical center about which the antenna scan is performed, in order to compensate for variation in angle of attack as flight progresses.

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SECTION III

PERFORMANCE CHECKS AND ADJUSTMENT PROCEDURES

3-1. PERFORMANCE CHECKS

3-2. A preliminary performance check of the Terrain Clearance Radar may be obtained by following the procedures below.

3-3. SYSTEM CHECK

a. Turn POWER switch on control panel to STBY. Standby lights should come on immediately.

b. Turn METER SEL switch on control panel to -300 volts. After a 30 to 40-second delay from the time the POWER switch is turned to STBY the meter reading should be 0.8 ±0.01 ma, indicating a normal supply voltage.

c. Rotate METER SEL switch to -150, +22.5, +150, +300, and +400. Meter should indicate 0.8 ±0.01 ma at each of these positions.

d. With KLYSTRON TUN switch turned to AUTO, turn METER SEL switch to AFC XTAL 1 and 2 in turn. Meter indication should fluctuate at a frequency of 0.5 to 2 cps, indicating that afc is searching.

3-4. E-SCOPE CHECK

a. Turn NOR, VIDEO, C. GATE switch to NOR.

b. Turn the BRIGHT control until range marks appear. A mark should appear every mile or 2 miles with RANGE switch turned to 10 or 20 MI, respectively.

c. Turn NOR, VIDEO, C. GATE selector on E-scope to C. GATE. A positive-going pulse should appear at 3 miles. This is the differentiated red range gate.

3-5. X-SCOPE CHECK

a. Turn BRIGHTNESS control on navigator's X-scope until scanning raster appears. Raster should just fill frame and should be presented in red and green, which combine to appear orange. The green may be centered

vertically with the VERT centering control. The red is then centered with SEPARATION control. The HORIZ centering control centers both the red and green rasters.

b. Reduce BRIGHTNESS until only a vertical line is visible. This is the marker which indicates location of E-scope profile being selected.

c. Rotate PROFILE SELECTOR control on E-scope through its range. This should cause line to move across width of X-scope image.

d. Repeat step a for pilot's X-scope (profile marker is not displayed on pilot's X-scope).

3-6. RECEIVER-TRANSMITTER CHECK

a. Turn METER SEL switch to MAG X10 and POWER switch on control panel to RUN. The RUN indicator light should come on 5 to 6 minutes from the time the POWER switch was turned to STBY. When RUN light comes on, meter should indicate 5 to 7 ma.

b. Rotate METER SEL switch to AFC XTAL 1 and 2 successively. A steady meter reading of 0.1 to 0.5 ma should be obtained, indicating that afc has locked on.

c. Turn METER SEL switch to REC XTAL 1 and 2 successively. A meter reading of 0.1 to 0.6 ma should be obtained.

d. Turn NOR, VIDEO, C. GATE switch on E-scope to VIDEO and adjust BRIGHT if necessary so that video is visible on E-scope.

e. Turn KLYSTRON TUN selector on control panel to MAN.

f. Adjust KLYSTRON TUNING control for maximum video amplitude.

g. Turn KLYSTRON TUN selector to AUTO and check to see that video does not decrease in amplitude. The rms noise level should be 800 feet on 5000-foot scale, corresponding to 0.5 volt.

h. With POWER switch on control panel turned to STBY, connect Westinghouse 1JD8946 Noise Figure Test Set or equivalent to receiver-transmitter output and determine receiver noise figure. The value should be no greater than 13 db.

3-7. OUTPUT CHECK

a. Attach a K_a-band water load (with a pressurization capability of 40 pounds and calibrated to 50 watts) through a pressurizing waveguide section to the receiver-transmitter output.

b. Through appropriate waveguide, connect a spectrum analyzer to r-f sampling arm E1259.

c. Turn POWER selector switch to RUN. Water load should indicate 25 ±4 watts average power. Spectrum should be nearly symmetrical with major sidelobe but at least 8 db down from main lobe. Main lobe should have a spectrum width of 10 ±2 mc. A typical spectrum is shown in figure 3-1.

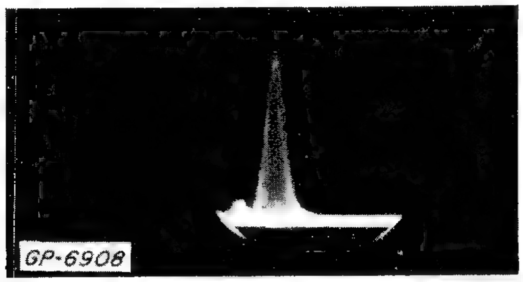

Figure 3-1. Magnetron Pulse Output Spectrum

3-8. ANTENNA ALIGNMENT

3-9. In order to center the scan about the aircraft's heading or to scan some desired area, the antenna must be aligned to correlate its coverage with the actual terrain coverage. For this purpose a sighting fixture is provided, which mounts on the antenna in a fixed position. Three front sights are provided, one for the center and one for each scan limit. These sights have been adjusted to coincide with the actual antenna sweep. If the antenna is used in a structure which may distort the sweep pattern, the sight adjustment may be checked as described below.

NOTE

During the sight adjustment check-out procedure the horizontal scan must not be stopped. The vertical scan may be stopped if desired.

3-10. SIGHT ADJUSTMENT CHECK. Proceed as follows:

a. Select a small target for alignment purposes and place radar set in operation.

b. While observing X-scope, move antenna horizontally until target is reduced to one-half its full width. This will result as target disappears off one side of sweep.

c. Align front sight corresponding to this sweep limit with vertical line in rear sight and with horizontal center of target.

d. Move antenna in opposite direction and repeat for other sweep limit.

e. Adjust center sight midway between sweep limits by measurement of distances between sights.

3-11. The vertical adjustment of the sight is checked as follows:

a. Set vertical scan sector at 10 degrees by measurement of vertical motion of antenna and by adjustment of limit switches.

b. Select a small target which can be positioned at either vertical limit of antenna scan. This is accomplished by positioning antenna mounting base, or by positioning the aircraft. Target should be lined up horizontally on scan center.

c. Place radar set in operation and position antenna base so that target is reduced to one-half its full width. This operation may be performed either at upper or lower limit of vertical scan.

d. Stop vertical scan by turning off radar and mount sight on antenna.

e. Position antenna against upper or lower limit and adjust movable horizontal line on rear sight to line up with horizontal line on center front sight.

f. Adjust movable horizontal line on rear sight to line up with horizontal line on center front sight. Steps e and f must be performed with front sight centered on target.

3-12. ANTENNA SECTOR COVERAGE CHECK. Having adjusted the sights as above, the sector coverage may be checked by the following procedure.

a. Mount sights on antenna.

b. Locate center and two limits of horizontal scan by looking along proper sights.

c. Position antenna against upper and lower limits of scan and sight through vertical sight to locate scan limits.

3-13. The following procedure is prescribed for alignment of the antenna with the aircraft's heading.

a. Align aircraft horizontally with some visual target. Aircraft must be positioned 5 degrees above target in vertical plane.

b. Position antenna at lower limit of scan.

c. Adjust antenna until crossed lines on rear and front center sights are centered on target.

SECTION IV

ELECTRICAL PARTS LIST

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		BLOWERS AND MOTORS		
B1201	1		575R075H01	Trans-rec
B1221	1		575R075H01	
B2001	2	1 for each X-scope	575R075H01	X-scope
B2201	1		575R075H01	E-scope
B2801	1		575R075H01	Power Supply
B2802	1		575R075H01	
B3201	1		575R075H01	Modulator
B3401	1		575R075H01	Synch-ronizer
B3801	1	Synchro	Kearfott Co. Inc RS-911-2A	Control Panel
B4001	1	Scan motor Slow scan Fast scan	Globe Ind. Inc. 33A641-18.78 Globe Ind. Inc. 83A121-6	Antenna
		CAPACITORS		
C1	2	22 uuf 300V	CM15C220J	X-scope sweep amp
C2	2	22 uuf 300V	CM15C220J	
C3	2	22 uuf 300V	CM15C220J	
C4	2	1.5-7 uuf	CV11A070	
C5	2	7-45 uuf	CV11A450	
C6	2	1.5-7 uuf	CV11A070	
C7	2	7-45 uuf	CV11A450	
C8	2	7-45 uuf	CV11A450	
C9	2	100 uuf 300V	CM15C101V	
C10	2	.01 uf 500V	CM35E103J	
C11	2	0.1 uf 200V	CP09A1EC104K	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
		CAPACITORS (Continued)			
C12	2	.1 uf	200V	CP09A1EC104K	X-scope sweep amp
C13	2	.01 uf	500V	CM35E103J	
C14	2	.1 uf	200V	CP09A1EC104K	
C15	2	100 uuf	300V	CM15C101J	
C16	2	.01 uf	500V	CM35E103J	
C17	2	0.1 uf	200V	CP09A1EC104K	
C18	2	.01 uf	500V	CM35E103J	
C19	2	.01 uf	500V	CM35E103J	
C20	2	.01 uf	500V	CM35E103J	
C21	2	100 uuf	300V	CM15C101J	
C22	2	.01 uf	500V	CM35E103J	
C23	2	1 uf	200V	CP09A1EC105K	
C24	2	1 uf	200V	CP09A1EC105K	
C25	2	1.5-7 uuf		CV11A070	
C26	2	1.5-7 uuf		CV11A070	
C27	2	7-45 uuf		CV11A450	
C28	2	7-45 uuf		CV11A450	
C29	2	.01 uf	500V	CM35E103J	
C30	2	10 uuf	300V	CM15C100J	
C31	2	100 uuf	300V	CM15C101J	
C32	2	1 uf	200V	CP09A1EC105K	
C201	1	100 uuf	300V	CM15C101J	E-scope vert amp
C202	1	100 uuf	300V	CM15C101J	
C203	1	22 uuf	300V	CM15C220J	
C204	1	22 uuf	300V	CM15C220J	
C205	1	0.1 uf	200V	CP09A3EC104K	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
CAPACITORS (Continued)					
C206	1	0.47 uf	200V	CP09A1EC474K	E-scope vert amp
C207	1	0.47 uf	200V	CP09A1EC474K	
C208	1	10-100 uuf	400V	1JC7797H02	
C209	1	10-100 uuf	400V	1JC7797H02	
C210	1	100 uuf	300V	CM15C101J	
C211	1	510 uuf	300V	CM15C511J	
C212	1	0.47 uf	200V	CP09A1EC474K	
C213	1	0.01 uf	300V	CM40E103J	
C214	1	1000 uuf	300V	CM20D102J	
C215	1	10 uuf	300V	CM15B100K	
C216	1	10 uuf	300V	CM15B100K	
C217	1	2 uf	500V	CP04A1KE105K	
C218	1	2 uf	500V	CP04A1KE105K	
C219	1	1.0 uf	200V	CP09A3EC105K	
C220	1	0.1 uf	200V	CP09A1EC104K	
C221	1	100 uuf	300V	CM15C101J	
C222	1	0.01 uf	600V	CP09A3EF103K	
C223	1	22 uuf	300V	CM15C220J	
C224	1	0.015 uf	600V	CP09A1EE153K	
C225	1	100 uuf	300V	CM15C101J	
C226	1	10 uuf	300V	CM15B100K	
C227	1	0.068 uf	200V	CP09A1EC683K	
C229	1	0.1 uf	200V	CP09A1EC104K	
C230	1	100 uuf	300V	CM15C101J	
C231	1	0.01 uf	600V	CP09A3EF103K	
C232	1	0.01 uf	600V	CP09A3EF103K	
C233	1	1000 uuf	300V	CM20D102J	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
		CAPACITORS (Continued)			
C234	1	0.01 uf	600V	CP09A3EF103K	E-scope vert amp
C235	1	0.01 uf	300V	CM40E103J	
C236	1	0.01 uf	300V	CM40E103J	
C237	1	620 uuf	300V	CM20D621J	
C238	1	22 uuf	300V	CM15C220J	
C239	1	22 uuf	300V	CM15C220J	
C501	1	1000 uuf	300V	CM20D102J	E-scope hor amp.
C502	1	22 uuf	300V	CM15C220J	
C503	1	22 uuf	300V	CM15C220J	
C504	1	22 uuf	300V	CM15C220J	
C505	1	330 uuf	300V	CM15D331J	
C506	1	.01 uf	200V	CP09A1EF103K	
C507	1	1000 uuf	300V	CM20D102J	
C508	1	22 uuf	300V	CM15C220J	
C509	1	.068 uf	200V	CP09A1EC683K	
C510	1	15 uuf	300V	CM15B150K	
C511	1	0.22 uf	100V	CP09A1EB224K	
C512	1	0.22 uf	400V	CP09A1EE224K	
C513	1	10-100 uuf	500V	1JC7797H02	
C514	1	.01 uf	400V	CP09A1EE103K	
C515	1	10-100 uuf	500V	1JC7797H02	
C517	1	0.1 uf	400V	CP09A1EE104K	
C518	1	.01 uf	200V	CP09A1EF103K	
C519	1	.01 uf	200V	CP09A1EF103K	
C520	1	1.0 uf	200V	CP09A3EC105K	
C521	1	.1 uf	400V	CP09A1EE104K	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
		CAPACITORS (Continued)			
C522	1	.1 uf	400V	CP09A1EE104K	E-scope hor amp.
C601	1	.01 uf	100V	CP09A3EB103K	Synch-ronizer
C602	1	5100 uuf	500V	CM35E512J	
C603	1	1000 uuf	300V	CM20D102J	
C604	1	510 uuf	300V	CM15C511J	
C605	1	1000 uuf	300V	CM20J102J	
C606	1	0.1 uf	100V	CP09A3EB104K	
C607	1	100 uuf	300V	CM15C101J	
C608	1	100 uuf	300V	CM15C101J	
C609	1	100 uuf	300V	CM15C101J	
C610	1	100 uuf	300V	CM15C101J	
C611	1	150 uuf	300V	CM15C151J	
C612	1	1000 uuf	300V	CM20D102J	
C613	1	.01 uf	100V	CP09A3EB103K	
C614	1	100 uuf	300V	CM15C101J	
C615	1	100 uuf	300V	CM15C101J	
C616	1	1000 uuf	300V	CM20D102J	
C617	1	100 uuf	300V	CM15C101J	
C618	1	100 uuf	300V	CM15C101J	
C619	1	100 uuf	300V	CM15C101J	
C620	1	100 uuf	300V	CM15C101J	
C621	1	1000 uuf	300V	CM20D102J	
C622	1	100 uuf	300V	CM15C101J	
C623	1	100 uuf	300V	CM15C101J	
C624	1	100 uuf	300V	CM15C101J	
C625	1	100 uuf	300V	CM15C101J	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
		CAPACITORS (Continued)			
C626	1	1000 uuf	300V	CM20D102J	Synch-ronizer
C627	1	100 uuf	300V	CM15C101J	
C628	1	100 uuf	300V	CM15C101J	
C629	1	100 uuf	300V	CM15C101J	
C630	1	100 uuf	300V	CM15C101J	
C631	1	1000 uuf	300V	CM30D102J	
C632	1	100 uuf	300V	CM15C101J	
C633	1	100 uuf	300V	CM15C101J	
C634	1	100 uuf	300V	CM15C101J	
C635	1	100 uuf	300V	CM15C101J	
C636	1	1000 uuf	300V	CM20D102J	
C637	1	100 uuf	300V	CM15C101J	
C638	1	150 uuf	300V	CM15C151J	
C639	1	100 uuf	300V	CM15C101J	
C640	1	100 uuf	300V	CM15C101J	
C641	1	1000 uuf	300V	CM20D102J	
C642	1	100 uuf	300V	CM15C101J	
C643	1	100 uuf	300V	CM15C101J	
C644	1	1000 uuf	300V	CM20D102J	
C645	1	1000 uuf	300V	CM20D102J	
C646	1	100 uuf	300V	CM15C101J	
C647	1	0.1 uf	100V	CP09A3EB104K	
C648	1	5100 uuf	500V	CM35E512J	
C649	1	5100 uuf	500V	CM35E512J	
C650	1	510 uuf	300V	CM15C511J	
C651	1	0.1 uf	200V	CP09A3EC104K	
C652	1	0.1 uf	200V	CP09A3EC104K	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
		CAPACITORS (Continued)			
C653	1	0.1 uf	100V	CP09A3EB104K	Synch-ronizer
C654	1	0.1 uf	200V	CP09A3EC104K	
C655	1	5100 uuf	500V	CM35E512J	
C656	1	0.1 uf	200V	CP09A3EC104K	
C657	1	0.1 uf	200V	CP09A3EC104K	
C658	1	0.1 uf	200V	CP09A3EC104K	
C659	1	5100 uuf	500V	CM35E512J	
C660	1	0.1 uf	100V	CP09A3EB104K	
C661	1	0.1 uf	200V	CP09A3EC104K	
C662	1	5100 uuf	500V	CM35E512J	
C663	1	22 uuf	300V	CM15C220J	
C664	1	.01 uf	100V	CP09A1EB103K	
C665	1	.01 uf	100V	CP09A1EB103K	
C666	1	100 uuf	300V	CM15C101J	
C667	1	22 uuf	300V	CM15C220J	
C668	1	3300 uuf	300V	CM30E332J	
C669	1	100 uuf	300V	CM15C101J	
C670	1	22 uuf	300V	CM15C220J	
C671	1	5 uuf	300V	CM15C050J	
C672	1	270 uuf	300V	CM15C271J	
C673	1	100 uuf	300V	CM15C101J	
C674	1	330 uuf	300V	CM15C331J	
C675	1	220 uuf	300V	CM15C221J	
C676	1	0.1 uf	200V	CP09A3EC104K	
C677	o	0.1 uf	100V	CP09A3EB104K	
C678	1	1000 uuf	300V	CM20D102J	
C679	1	22 uuf	300V	CM15C220J	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
CAPACITORS (Continued)					
C680	1	620 uuf	300V	CM20D621J	Synch-ronizer
C681	1	220 uuf	300V	CM15C221J	
C682	1	0.1 uf	200V	CP09A3EC104K	
C683	1	0.1 uf	100V	CP09A3EB104K	
C684	1	100 uuf	300V	CM15C101J	
C685	1	22 uuf	300V	CM15C220J	
C686	1	330 uuf	300V	CM15C331J	
C687	1	100 uuf	300V	CM15C101J	
C688	1	22 uuf	300V	CM15C220J	
C689	1	180 uuf	300V	CM15C181J	
C690	1	56 uuf	300V	CM15C560J	
C691	1	2200 uuf	300V	CM30E222J	
C693	1	.01 uf	100V	CP09A3EB103K	
C694	1	100 uuf	300V	CM15C101J	
C695	1	.01 uf	600V	CP09A3EF103K	
C696	1	0.1 uf	200V	CP09A1EC104K	
C697	1	100 uuf	300V	CM15C101J	
C698	1	22 uuf	300V	CM15C220J	
C699	1	8200 uuf	300V	CM35E822G	
C701	1	100 uuf	300V	CM15C101J	
C702	1	100 uuf	300V	CM15C101J	
C703	1	100 uuf	300V	CM15C101J	
C704	1	100 uuf	300V	CM15C101J	
C705	1	1000 uuf	300V	CM20D102J	
C706	1	100 uuf	300V	CM15C101J	
C707	1	100 uuf	300V	CM15C101J	
C708	1	.01 uf	100V	CP09A3EB103K	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
		CAPACITORS (Continued)			
C709	1	100 uuf	300V	CM15C101J	Synch-ronizer
C1201	1	1 uf	400V	1JC1746H37	Trans-mitter receiver
C1202	1	1 uf	400V	1JC1746H37	
C1203	1	.47 uf	400V	CP09A1EB474K	
C1223	1	.01 uf	400V	CP09A1EE103K	
C1224	1	.01 uf	100V	CP09A1EB103K	
C1225	1	.01 uf	100V	CP09A1EB103K	
C1227	1	.01 uf	100V	CP09A1EB103K	
C1228	1	.01 uf	100V	CP09A1EB103K	
C1401	1	.001 uf	200V Allen Bradley	Type SOB	Preamp
C1402	1	.001 uf	200V Allen Bradley	Type SOB	
C1403	1	.001 uf	200V Allen Bradley	Type SOB	
C1404	1	.001 uf	200V Allen Bradley	Type SOB	
C1405	1	.001 uf	500V	CK61Y102Z	
C1406	1	.001 uf	500V	CK61Y102Z	
C1407	1	7-45 uuf	500V	CV11C450	
C1408	1	.001 uf	200V	2JC2701H01	
C1409	1	1.8 uuf	500V	575R343H01	
C1410	1	.001 uf	200V	2JC2701H01	
C1411	1	.001 uf	200V	2JC2701H01	
C1412	1	.001 uf	200V	2JC2701H01	
C1413	1	.001 uf	200V	2JC2701H01	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
		CAPACITORS (Continued)			
C1414	1	.001 uf	200V	2JC2701H01	Preamp
C1415	1	.001 uf	200V	2JC2701H01	
C1416	1	470 uuf	500V	2JC2701H02	
C1417	1	.001 uf	200V	2JC2701H01	
C1418	1	.001 uf	200V	2JC2701H01	
C1419	1	470 uuf	500V	2JC2701H02	
C1420	1	.001 uf	200V	2JC2701H01	
C1421	1	.001 uf	200V	2JC2701H01	
C1422	1	.001 uf	200V	2JC2701H01	
C1423	1	.001 uf	200V	2JC2701H01	
C1424	1	.001 uf	200V	2JC2701H01	
C1601	1	.001 uf	200V	2JC2701H01	Postamp
C1602	1	680 uuf	500V	2JC2701H02	
C1603	1	.001	200V	2JC2701H01	
C1604	1	680 uuf	500V	2JC2701H02	
C1605	1	.001 uf	200V	2JC2701H01	
C1606	1	680 uuf	500V	2JC2701H02	
C1607	1	.001 uf	200V	2JC2701H01	
C1608	1	680 uuf	500V	2JC2701H02	
C1609	1	.001 uf	200V	2JC2701H01	
C1610	1	680 uuf	500V	2JC2701H02	
C1611	1	680 uuf	500V	2JC2701H02	
C1612	1	.001 uf	200V	2JC2701H01	
C1613	1	.001 uf	200V	2JC2701H01	
C1614	1	680 uuf	500V	2JC2702H02	
C1615	1	.001 uf	200V	2JC2701H01	
C1616	1	7 uuf	200V	CC20CG070D	
C1617	1	.001 uf	200V	2JC2701H01	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
CAPACITORS (Continued)					
C1618	1	.001 uf	500V	2JC2444H01	Postamp
C1619	1	300 uuf	500V	CM15C301J	
C1620	1	.001 uf	200V	2JC2701H01	
C1621	1	.001 uf	200V	2JC2701H01	
C1622	1	.001 uf	200V	2JC2701H01	
C1623	1	.001 uf	200V	2JC2701H01	
C1624	1	.001 uf	200V	2JC2701H01	
C1425	1	.068 uf	200V	CP09A3EC683K	
C1626	1	.068 uf	200V	CP09A3EC683K	
C1801	1	1.5-12 uuf	200V	1JC8179H01	AFC-IF
C1802	1	1.5-12 uuf	200V	1JC8179H01	
C1803	1	.001 uf	200V	CB21QX102K	
C1804	1	.001 uf	200V	CB21QX102K	
C1805	1	.001 uf	200V	CB21QX102K	
C1806	1	7 uf	200V	CC20CH070D	
C1807	1	30 uuf	200V	CC20RH300J	
C1808	1	.001 uf	300V	CB21QX102K	
C1809	1	.001 uf	300V	CB21QX102K	
C1810	1	120 uuf	200V	CC25CH121D	
C1811	1	100 uuf	200V	CC25CH101D	
C1812	1	.0047 uf	500V	CK62Y472Z	
C1813	1	.01 uf	500V	CK63Y103Z	
C1814	1	200 uuf	300V	CM15C201J	
C1815	1	.001 uf	400V	CK61Y102Z	
C1816	1	.0047 uf	500V	CK62Y472Z	
C1818	1	.01 uf	500V	CK63Y103Z	
C1819	1	.01 uf	100V	CP09A1KB103K	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
		CAPACITORS (Continued)			
C1820	1	.001 uf	200V	2JC2701H01	AFC-IF
C1821	1	.001 uf	200V	CB21QX102K	
C1822	1	.001 uf	200V	CB21QX102K	
C1823	1	.001 uf	200V	CB21QX102K	
C1824	1	.001 uf	200V	CB21QX102K	
C1825	1	.001 uf	200V	2JC2701H01	
C1826	1	.001 uf	200V	2JC2701H01	
C1827	1	.001 uf	200V	CB21QX102K	
C1828	1	.001 uf	200V	2JC2701H01	
C1829	1	.001 uf	200V	2JC2701H01	
C1830	1	.001 uf	200V	CB21QX102K	
C1831	1	.001 uf	200V	CB21QX102K	
C1832	1	.001 uf	200V	CB21QX102K	
C1833	1	.001 uf	200V	2JC2701H01	
C1834	1	.001 uf	200V	CB21QX102K	
C2001	2	.01 uf	3000V	2JC2383H17	X-scope
C2002	2	1 uf	200V	CP09A3EC105K	
C2003	2	1 uf	400V	CP09A1KE105K	
C2004	2	1 uf	200V	CP09A1EC105K	
C2201	1	.01 uf	3000V	2JC2383H17	E-scope
C2801	1	2 uf	400V	1JC4825H97	Power supply
C2802	1	2 uf	400V	1JC4825H97	
C2803	1	2 uf	400V	1JC4825H97	
C2804	1	2 uf	400V	1JC4825H97	
C2805	1	2 uf	400V	1JC4825H97	
C2806	1	0.1 uf	400V	CP09A1EE104K	
C2807	1	0.1 uf	400V	CP09A1EE104K	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
CAPACITORS (Continued)					
C2808	1	0.1 uf	400V	CP09A1EE104K	Power supply
C2809	1	0.1 uf	400V	CP09A1EE104K	
C2810	1	10 uf	600V	Gudeman No. XHF17576	
C2811	1	10 uf	600V	Gudeman No. XHF17576	
C2812	1	10 uf	600V	Gudeman No. XHF17576	
C2813	1	10 uf	600V	Gudeman No. XHF17576	
C2814	1	10 uf	600V	Gudeman No. XHF17576	
C3201	1	0.1 uf	5000V	AMP No. PS3951A	Modulator
C3202	1	1 uf	100V	CP09A1EB105K	
C3203	1	.47 uf	400V	CP09A1EE474K	
C3204	1	500 uuf	2500V	CM45B511J	
C3205	1	3900 uuf	300V	CM35B392J	
C3206	1	.1 uf	400V	CP09A1EE104K	
C3207	1	150 uf	30V	1JC4817H01	
C3208	1	.01 uf	100V	CP09A1EB103K	
C3209	1	.01 uf	200V	CP09A1EC103K	
C3210	1	.0033 uf	400V	CP09A1EE332K	
C3211	1	.047 uf	100V	CP09A1EB473K	
C3801	1	.001 uf	500V	CY20C102K	Control panel
C3802	1	.001 uf	500V	CY20C102K	
C3803	1	.001 uf	500V	CY20C102K	
C3804	1	.001 uf	500V	CY20C102K	
C3805	1	.001 uf	500V	CY20C102K	
C3806	1	.001 uf	500V	CY20C102K	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
CAPACITORS (Continued)					
C3807	1	.001 uf	500V	CY20C102K	Control panel
C3808	1	.001 uf	500V	CY20C102K	
C3809	1	.001 uf	500V	CY20C102K	
C3810	1	.001 uf	500V	CY20C102K	
C3811	1	.001 uf	500V	CY20C102K	
C3812	1	.001 uf	500V	CY20C102K	
C3813	1	.001 uf	500V	CY20C102K	
C3814	1	.001 uf	500V	CY20C102K	
C3815	1	.001 uf	500V	CY20C102K	
C3816	1	.001 uf	500V	CY20C102K	
C3817	1	.001 uf	500V	CY20C102K	
C3818	1	.001 uf	500V	CY20C102K	
C3819	1	.001 uf	500V	CY20C102K	
C3820	1	.001 uf	500V	CY20C102K	
C4001	1	1000 uuf	300V	CM20D102J	Antenna jct. box
C4002	1	.01 uf	100V	CP09A1EB103K	
C4003	1	1000 uuf	300V	CM20D102J	
C4004	1	1 uf	200V	CP09A1EC105K	
C4005	1	.1 uf	200V	CP09A3EC104K	
C4006	1	.1 uf	200V	CP09A3EC104K	
C4007	1	1000 uuf	300V	CM20D102J	
C4008	1	1 uf	200V	CP09A1EC105K	Antenna
C4009	1	1 uf	200V	CP09A1EC105K	Antenna
C4010	1	1 uf	200V	CP09A1EC105K	Antenna jct. box

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
DIODES				
CR1	2	1N214	1JC7875H16	X-scope sweep amp
CR2	2	1N214	1JC7875H16	
CR5	2	1N200	1JC7875H02	
CR6	2	1N200	1JC7875H02	
CR7	2	1N221	1JC7875H25	
CR8	2	1N210	1JC7875H12	
CR9	2	1N210	1JC7875H12	
CR201	1	1N214	1JC7875H16	E-scope vert amp
CR202	1	1N214	1JC7875H16	
CR203	1	1N210	1JC7875H12	
CR204	1	1N210	1JC7875H12	
CR205	1	1N210	1JC7875H12	
CR206	1	1N210	1JC7875H12	
CR207	1	1N218	1JC7875H22	
CR208	1	1N218	1JC7875H22	
CR209	1	1N218	1JC7875H22	
CR210	1	1N210	1JC7875H12	
CR211	1	1N210	1JC7875H12	
CR212	1	1N204	1JC7875H06	
CR213	1	1N204	1JC7875H06	
CR214	1	1N210	1JC7875H12	
CR215	1	1N210	1JC7875H12	
CR216	1	1N210	1JC7875H12	
CR501	1	1N210	1JC7875H12	E-scope hor amp

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		DIODES (Continued)		
CR502	1	1N218	1JC7875H22	E-scope hor amp
CR503	1	1N218	1JC7875H22	
CR504	1	1N206	1JC7875H08	
CR505	1	1N210	1JC7875H12	
CR506	1	1N214	1JC7875H16	
CR507	1	1N214	1JC7875H16	
CR508	1	1N214	1JC7875H16	
CR509	1	1N214	1JC7875H16	
CR510	1	1N214	1JC7875H16	
CR601	1	1N206	1JC7875H08	Synch-ronizer
CR602 thru CR621	1ea	1N204	1JC7875H06	
CR622	1	1N210	1JC7875H12	
CR623	1	1N200	1JC7875H02	
CR624	1	1N206	1JC7875H08	
CR627	1	1N210	1JC7875H12	
CR628	1	1N218	1JC7875H22	
CR629	1	1N218	1JC7875H22	
CR630	1	1N218	1JC7875H22	
CR631	1	1N218	1JC7875H22	
CR632	1	1N210	1JC7875H12	
CR633	1	1N210	1JC7875H12	
CR634	1	1N214	1JC7875H16	
CR635	1	1N214	1JC7875H16	
CR636	1	1N210	1JC7875H12	
CR637	1	1N204	1JC7875H06	
CR638	1	1N204	1JC7875H06	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		DIODES (Continued)		
CR639	1	1N210	1JC7875H12	Synch-ronizer
CR640	1	1N204	1JC7875H06	
CR641	1	1N204	1JC7875H06	
CR642	1	1N206	1JC7875H08	
CR643	1	1N206	1JC7875H08	
CR644	1	1N206	1JC7875H08	
CR1221	1		2JC2806H07	Trans-rec
CR1401	1	Matched reversed pair	1N53BR	Preamp
CR1402	1		1N53BR	
CR1601	1		2JC2719H01	Postamp
CR1602	1		2JC2719H01	
CR1603	1		1JC7877H10	
CR1604	1		1JC7877H10	
CR1801	1	D938M	D938M	AFC-IF
CR1802	1	D938M	D938M	
CR1803	1		2JC2806H06	
CR2001	2	1N218	1JC7875H22	X-scope
CR2201	1	1N218	1JC7875H22	E-scope
CR2202	1	1N218	1JC7875H22	
CR2203	1	1N218	1JC7875H22	
CR2801	1	Rectifier assy	Gen Elec 4JA411CF2AD1	Power supply
CR2802	1	Rectifier assy	Gen Elec 4JA411CF2AD1	
CR2803	1	Rectifier assy	Gen Elec 4JA411CF1AD1	
CR2804	1	Rectifier assy	Gen Elec 4JA411CF1AD1	
CR2805	1	Rectifier assy	Gen Elec 4JA411CF2AD1	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
DIODES (Continued)					
CR2806	1	1N430A	CR2806 thru CR2833 are Hoffman Elec diodes	1N430A	Power supply
CR2807	1	ZA60-2		ZA60-2	
CR2808	1	ZA10-2		ZA10-2	
CR2809	1	ZA60-2		ZA60-2	
CR2810	1	ZA10-2		ZA10-2	
CR2811	1	ZA60-2		ZA60-2	
CR2812	1	ZA10-2		ZA10-2	
CR2813	1	1N430A		1N430A	
CR2814	1	ZA60-2		ZA60-2	
CR2815	1	ZA10-2		ZA10-2	
CR2816	1	ZA60-2		ZA60-2	
CR2817	1	ZA10-2		ZA10-2	
CR2818	1	ZA60-2		ZA60-2	
CR2819	1	ZA10-2		ZA10-2	
CR2820	1	1N430A		1N430A	
CR2821	1	ZA60-2		ZA60-2	
CR2822	1	ZA10-2		ZA10-2	
CR2823	1	ZA60-2		ZA60-2	
CR2824	1	ZA10-2		ZA10-2	
CR2825	1	ZA60-2		ZA60-2	
CR2826	1	ZA10-2		ZA10-2	
CR2827	1	1N430A		1N430A	
CR2828	1	ZA60-2		ZA60-2	
CR2829	1	ZA10-2		ZA10-2	
CR2830	1	ZA60-2		ZA60-2	
CR2831	1	ZA10-2		ZA10-2	

REF DESIG	QTY PER EQUIP	DESCRIPTION		DRAWING OR MFR. NO.	MAJOR COMPONENT
		DIODES (Continued)			
CR2832	1	ZA60-2	Hoffman Elec.	ZA60-2	Power supply
CR2833	1	ZA10-2	Hoffman Elec.	ZA10-2	
CR3201 thru CR3230	30			2JC3281H02	Modulator
CR3231 thru CR3240	10			2JC3281H02	
CR4001	1	1N206		1JC7875H08	Antenna
CR4002	1	1N206		1JC7875H08	
CR4003	1	1N214		1JC7875H16	Antenna jct box
CR4004	1	1N214		1JC7875H16	
CR4005	1	1N214		1JC7875H16	
		LAMPS			
DS2201	1	Lamp		AN3140-327	E-scope
DS2202	1			AN3140-327	
DS2203	1			AN3140-327	
DS2204	1			AN3140-327	
DS2205	1			AN3140-327	
DS2206	1			AN3140-327	
DS3401	1			MS25237-327	Synchronizer
DS3801	1			AN3140-327	Control panel
DS3802	1			AN3140-327	
DS3803	1			AN3140-327	
DS3804	1			AN3140-327	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		LAMPS (Continued)		
DS3805	1		AN3140-327	Control panel
DS3806	1		AN3140-327	
		PANEL LIGHTS		
XDS2201 thru XDS2206	6		Dialco TT55-5030-B7	E-scope
XDS3401	1		Dialco TT55A-5030-B7	Synch-ronizer
XDS3801 thru XDS3805	5		Dialco TT55-5030-B7	Control panel
XDS3806	1	See note 3 on Dwg. No. 703R156		
		R-F PLUMBING		
E1251	1	Attenuator	406R453G01	Trans-rec
E1252	1	Waveguide assy.	406R455G01	
E1253	1	Attenuator	306R420G01	
E1254	1	Rat race	Microwave Assoc. Model MA538-B	
E1256	1	Attenuator	406R452G01	
E1257	1	Attenuator	406R441G01	
E1258	1	Waveguide assy.	406R437G01	
E1259	1	Attenuator take-off and pressure fitting	406R434G01	
E1260	1	Waveguide assy.	406R428G01	
E1261	1	Waveguide assy.	306R408G01	
E1262	1	Waveguide assy.	406R445G01	
E1263	1	Waveguide assy.	306R412G01	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		R-F PLUMBING (Continued)		
E1264	1	Low-power termination	Microwave Assoc. Model 540-A	Trans-rec
E1265	1	Directional coupler	1036W9	
E1266	1	Load isolator	Cascade Res Corp KA131	
		FUSES		
F2801	2	1A	MS90078-9-1	Power supply
F2802	2	.125A	MS90078-4-1	
F2803	2	1A	MS90078-9-1	
F2804	2	.75A	MS90078-8-1	
F2805	2	.375A	MS90078-6-1	
F2806	2	.125A	MS90078-9-1	
F2807	1	6A	MS90078-15-1	
F2808	1	6A	MS90078-15-1	
F2809	1	6A	MS90078-15-1	
F2810	1	2A	MS90078-11-1	
F3801	2	3A	MS90078-12-1	Control panel
F3802	2	3A	MS90078-12-1	
F3803	2	3A	MS90078-12-1	
F3804	2	8A	MS90079-4-1	
F3805	2	5A	MS90078-14-1	
		FUSE HOLDERS		
XF2801 thru XF2810	10		575R143H01	Power supply

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		FUSE HOLDERS (Continued)		
XF3801	1		Fuse Ind. Corp. IND-300-A-white	Control panel
XF3802	1		IND-300-A-white	
XF3803	1		IND-300-A-white	
XF3804	1		IND-300-A-white	
XF3805	1		IND-300-A-red	
		CONNECTORS, RECEPTACLE		
J1	2		1JC7836H01	X-scope sweep amp
J2	2		1JA4821H03	
J3	2		1JA4821H03	
J4	2		Winchester PM1S	
J5	2	Coax	Microdot Inc 31-52	
J6	2	Coax	Microdot Inc 31-52	
J7	2		Winchester PM1S	
J8	2	Coax	Microdot Inc 31-52	
J9	2	Coax	Microdot Inc 31-52	
J201 thru J204	4	Coax	Microdot Inc 31-52	E-scope vert sweep
J205	1		1JA4821H03	
J206	1		1JA7544H02	
J207	1		1JA7544H03	
J208	1		1JA4821H02	
J501	1	Coax	Microdot Inc 31-52	E-scope hor sweep
J502	1		1JA4821H03	
J504	1		1JA2629H02	
J505	1		1JA4821H02	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		CONNECTORS, RECEPTACLE (Continued)		
J1201	1		MS3102E-22-19P	Trans-rec
J1202	1	High-voltage coax	UG-496/U	
J1221	1		MS3102E-28-11P	
J1222	1	Coax	UG90/U	
J1401	1		1JC7901H01	Preamp
J1402	1	Coax	UG290/U	
J1601	1		1JA2629H03	Postamp
J1602	1	Coax	UG290/U	
J1603	1	Coax	UG290/U	
J1604	1	Coax	UG290/U	
J1801	1		1JC8115H03	AFC-IF
J2001	2		MS3102E-32-13P	X-scope
J2002 thru J2005	8	Coax	UG-492B/U	
J2008	2		MS3102E-14S-7P	
J2011	2		MS3102E-14S-7P	
J2012	2		1JA2290H01	
J2202	1		MS102E-18-8S	E-scope
J2203 thru J2206	4	Coax	UG492A/U	
J2209	1	Coax	UG492A/U	
J2801	1		MS3102E-20-16P	Power supply
J2802	1		MS3102E-22-19SW	
J2803	1		MS3102E-22-14PY	
J2804	1		MS3102E-22-19SX	
J2805	1		MS3102E-16S-1SW	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
CONNECTORS, RECEPTACLE (Continued)				
J2806	1		MS3102E-22-14SW	Power supply
J3201	1		MS3102E-22-14PW	Modulator
J3202	1	Coax	UG290/U	
J3203	1	High-voltage coax	UG496/U	
J3401	1		AN3102E-22-14P	Synch-ronizer
J3402 thru J3407	6	Coax	UG262/U	
J3414	1		1JA2291H01	
J3415	1		1JA2290H01	
J3416	1		1JA2290H01	
J3801	1		MS3102E-20-33P	Control panel
J3802	1		MS3102E-22-14SY	
J3803	1		MS3102E-28-12S	
J3804	1		MS3102E-32-13S	
J3805	1		MS3102E-32-13S	
J3806	1		MS3102E-22-14S	
J3807	1		MS3102E-22-19SY	
J4002	1		MS3102E-12S-3S	Antenna jct. box
J4003	1		MS3102E-18-8P	
J4004	1		UG290/U	
J4005	1		MS3102E-22-19PX	
J4006	1		MS3102E-22-19PX	
J4007	1		UG290/U	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RELAYS		
K1	2		1JC4860H06	X-scope sweep amp
K201	1	28 volts	1JC7769H08	E-scope vert amp
K202	1	28 volts	1JC7769H08	
K1221	1	28 volts	1JC4860H03	Trans-rec
K2801	1	28 volts	1JC8156H01	Power supply
K2802	1	28 volts	1JC7790H01	
K2803	1		1JB6251H08	
K2804	1		1JB6251H08	
K2805 thru K2808	4	Oven	503R275H01	
K3201	1		1JC8156H01	Modulator
K3202	1	Overload	1JB2393H01	
K3801	1		1JC8156H01	Control panel
K3802	1		1JB6251H02	
K3803	1		1JB6251H02	
K3804	1		1JB6251H02	
K3805	1		1JC7769H08	
K4001	1	Latching	Potter and Brumfield KB17D	Antenna
		INDUCTORS (CHOKES)		
L1 thru L10	16	Coil 300 uh	1JC8020H36	X-scope sweep amp
L201	1	Coil 300 uh	1JC8020H36	E-scope vert. amp

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		INDUCTORS (CHOKES) (Continued)		
L202	1	Coil 300 uh	1JC8020H36	E-scope vert amp
L203	1	1000 uh	Cambridge Therm. Corp. X2082-14	
L204	1	1000 uh	X2082-14	
L501	1	Coil 300 uh	1JC8020H36	E-scope hor. amp
L502	1	Coil 300 uh	1JC8020H36	
L601 thru L604	4	15 uh	1JC8020H05	Synch-ronizer
L1401 thru L1407	7	2.2 uh	1JC8059H05	Preamp
L1601 thru L1605	5	2.2 uh	1JC8059H05	Postamp
L1801 thru L1804	4	2.2 uh	1JC8059H05	AFC-IF
L1805	1	Variable inductor	2JC2706H08	
L3201	1	Choke 16.1 H	2JC2564-H01	Modulator
L3202	1	2.6 uh See Note 1 on 703R130 (M) Meter		
		METER		
M3801	1	0-1 ma	Simpson type 25R	Control panel

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		CONNECTORS, PLUG		
P1	2		1JC7836H02	X-scope sweep amp
P2	2		1JA4821H02	
P3	2		1JA4821H02	
P4	2		Winchester PM1P	
P5	2	Coax	Microdot Inc 32-66	
P6	2	Coax	Microdot Inc 32-66	
P7	2		Winchester PM1P	
P8	2	Coax	Microdot Inc 32-66	
P9	2	Coax	Microdot Inc 32-66	
P201	1	Coax (cable)	406R407G01	E-scope vert amp
P202	1	Coax (cable)	406R407G02	
P203	1	Coax (cable)	406R407G03	
P204	1	Coax (cable)	406R407G03	
P205	1		406R408G01	
P206	1		1JA7544H01	
P207	1		1JA7544H04	
P208	1		1JA4821H01	
P501	1	Coax	406R407G04	E-scope hor amp
P502	1		1JA4821H04	E-scope hor amp
P504	1		1JA2629H01	
P505	1		1JA4821H01	
P1201	1		MS3106E-22-19S	Trans-rec
P1202	1	High-voltage coax	UG59D/U	
P1221	1		MS3106E-28-11S	
P1222	1		UG260B/U	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		CONNECTORS, PLUG (Continued)		
P1401	1		1JC7901H02	Trans-rec
P1402	1	Coax	UG260/U	
P1601	1		1JA2629H04	Postamp
P1602	1	Coax	UG262/U	
P1603	1	Coax	UG262/U	
P1604	1	Coax	UG262/U	
P1801	1		1JC8115H02	AFC-IF
P2001	2		MS3106E-32-13S	X-scope
P2002A	2	Coax	UG260B/U	
P2002B	2	Coax	Microdot Inc 32-32	
P2002C	2	Coax	Microdot Inc 32-68	
P2003A	2	Coax	UG260B/U	
P2003B	2	Coax	Microdot Inc 32-22	
P2003C	2	Coax	Microdot Inc 32-68	
P2004A	2	Coax	UG260B/U	
P2004B	2	Coax	Microdot Inc 32-22	
P2004C	2	Coax	Microdot Inc 32-68	
P2005A	2	Coax	UG260B/U	
P2005B	2	Coax	Microdot Inc 32-22	
P2005C	2	Coax	Microdot Inc	
P2008	2		MS3108E-14S-7S	
P2009	2		2JC2812H01	
P2010	2		2JC2812H01	
P2011	2		MS3108E-14S-7S	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
CONNECTORS, PLUG (Continued)				
P2202	1		MS3106E-18-8P	E-scope
P2210	1	Cable	2JC2812H01	
P2211	1		MS3106E-14S-7S	
P2801	1		MS3106E-20-16S	Power supply
P2802	1		MS3106E-22-19PW	
P2803	1		MS3106E-22-14SY	
P2804	1		MS3106E-22-19PX	
P2805	1		MS3106E-16S-1SW	
P2806	1		MS3106E-22-14PW	
P3201	1		MS3106E-22-14SW	Modulator
P3202	1	Coax	UG260B/U	
P3203	1	High-voltage coax	UG59D/U	
P3401	1		AN3106E-22-14S	Synch-ronizer
P3402 thru P3407	6	Coax	UG260B/U	
P3414	1		1JA2291H02	
P3415	1		1JA2290H02	
P3416	1		1JA2290H02	
P3801	1		MS3106E-20-33S	Control panel
P3802	1		MS3106E-22-14PY	
P3803	1		MS3106E-28-12P	
P3804	1		MS3106E-32-13S	
P3805	1		MS3106E-32-13S	
P3806	1		MS3106E-22-14P	
P3807	1		MS3106E-22-19PY	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		CONNECTORS, PLUG (Continued)		
P4002	1		MS3106E-12S-3P	Antenna jct. box
P4003	1		MS3106E-18-8S	
P4004	1	Coax	UG260B/U	
P4005	1		MS3106E-22-19SX	
P4006	1		MS3106E-22-19SY	
P4007	1	Coax	UG260B/U	
		TRANSISTORS		
Q601	1	2N332	Texas Inst. 2N332	Synch-ronizer
Q602	1	2N332	2N332	
Q603	1	2N328	Raytheon Mfg. 2N328	
Q604	1	2N335	Texas Inst. 2N335	
Q605 thru Q626	22	2N333	Texas Inst. 2N333	
		RESISTORS		
R1	2	Variable 1 meg	2JC2779H48	X-scope sweep amp
R2	2	10k 1/2w	RC20GF103J	
R3	2	27k 1w	RC32GF273J	
R4	2	10k 1/2w	RC20GF103J	
R5	2	110k 1/2w	RC20GF114J	
R6	2	110k 1/2w	RC20GF114J	
R7	2	10k 1/2w	RC20GF103J	
R8	2	2.2k 1/2w	RC20GF222J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R9	2	10k 1/2w	RC20GF103J	X-scope sweep amp
R10	2	18k 1/2w	RC20GF183J	
R11	2	18k 1/2w	RC20GF183J	
R12	2	10k 1/2w	RC20GF103J	
R13	2	10 meg 1/2w	RC20GF106J	
R14	2	120k 1/2w	RC20GF124J	
R15	2	43k 1/2w	RC20GF433J	
R16	2	10k 1/2w	RC20GF103J	
R17	2	10k 1/2w	RC20GF103J	
R18	2	10k 1/2w	RC20GF103J	
R19	2	1 meg 1/2w	RC20GF105J	
R20	2	10 meg 1/2w	RC20GF106J	
R21	2	56k 1/2w	RC20GF563J	
R22	2	6.8k 1/2w	RC20GF682J	
R23	2	1 meg 1/2w	RC20GF105J	
R24	2	10k 1w	RC32GF103J	
R25	2	5.1k 1/2w	RC20GF512J	
R26	2	7.5k 2w	RC42GF752J	
R27	2	7.5k 2w	RC42GF752J	
R28	2	300k 1/2w	RC20GF304J	
R29	2	10k 2w	RC42GF103J	
R30	2	300k 1/2w	RC20GF304J	
R31	2	5.6k 1/2w	RC20GF562J	
R32	2	10k 1/2w	RC20GF103J	
R33	2	1 meg 1/2w	RC20GF105J	
R34	2	56k 1/2w	RC20GF563J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R35	2	6.8k 1w	RC32GF682J	X-scope sweep amp
R36	2	5.1k 1/2w	RC20GF512J	
R37	2	7.5k 1/2w	RC20GF752J	
R38	2	7.5k 1/2w	RC20GF752J	
R39	2	5.6k 1w	RC32GF562J	
R40	2	8.6k 25w	1JA7519H43	
R41	2	3.3k 2w	RC42GF332J	
R42	2	3.3k 2w	RC42GF332J	
R43	2	8.6k 25w	1JA7519H43	
R44	2	510k 1/2w	RC20GF514J	
R45	2	1k 1/2w	RC20GF102J	
R46	2	68k 1/2w	RC20GF683J	
R47	2	22k 1/2w	RC20GF223J	
R49	2	22k 1/2w	RC20GF223J	
R50	2	200 ohms 1/2w	RC20GF201J	
R51	2	Variable 10k 1/2w	2JC2779H42	
R53	2	Variable 2.5k	2JC2779H62	
R54	2	470k 1/2w	RC20GF474J	
R55	2	2.4k 1/2w	RC20GF242J	
R56	2	180k 1/2w	RC20GF184J	
R57	2	5.1k 1w	RC32GF512J	
R59	2	Variable 2.5 meg	2JC2779H49	
R64	2	91 ohms 1/2w	RC20GF910J	
R66	2	1 meg 1/2w	RC20GF105J	
R69	2	200 ohms 1/2w	RC20GF201J	
R73	2	200 ohms 1/2w	RC20GF201J	
R74	2	1k 1/2w	RC20GF102J	
R75	2	5.1k 1/2w	RC20GF512J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R76	2	1 meg 1/2w	RC20GF105J	X-scope sweep amp
R77	2	100k 1/2w	RC20GF104J	
R78	2	100 ohms 1/2w	RC20GF101J	
R79	2	10k 1/2w	RC20GF103J	
R80	2	100k 1/2w	RC20GF104J	
R81	2	130k 1/2w	RC20GF134J	
R82	2	110k 1/2w	RC20GF114J	
R83	2	10k 1/2w	RC20GF103J	
R84	2	10k 1/2w	RC20GF103J	
R85	2	100k 1/2w	RC20GF104J	
R86	2	33k 1/2w	RC20GF333J	
R87	2	51k 1/2w	RC20GF513J	
R88	2	100k 1/2w	RC20GF104J	
R89	2	2 meg 1/2w	RC20GF205J	
R92	2	Variable 1 meg	2JC2779H48	
R93	2	1 meg 1/2w	RC20GF105J	
R94	2	10k 1w	RC32GF103J	
R95	2	27k 1w	RC32GF273J	
R96	2	10k 1/2w	RC20GF103J	
R97	2	56k 1/2w	RC20GF563J	
R98	2	5.6k 1/2w	RC20GF562J	
R99	2	120k 1/2w	RC20GF124J	
R101	2	10 meg 1/2w	RC20GF106J	
R102	2	43k 1w	RC32GF433J	
R103	2	5.6k 1/2w	RC20GF562J	
R104	2	56k 1/2w	RC20GF563J	
R105	2	6.8k 1/2w	RC20GF682J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R106	2	1 meg 1/2w	RC20GF105J	X-scope sweep amp
R107	2	10k 1/2w	RC20GF103J	
R108	2	5.1k 1/2w	RC20GF512J	
R109	2	300k 1/2w	RC20GF304J	
R110	2	10k 2w	RC42GF103J	
R111	2	300k 1/2w	RC20GF304J	
R112	2	7.5k 2w	RC42GF752J	
R113	2	7.5k 2w	RC42GF752J	
R114	2	10k 1w	RC32GF103J	
R115	2	1 meg 1/2w	RC20GF105J	
R116	2	6.8k 1w	RC32GF682J	
R117	2	5.1k 1/2w	RC20GF512J	
R118	2	7.5k 1/2w	RC20GF752J	
R119	2	7.5k 1/2w	RC20GF752J	
R120	2	5.6k 1w	RC32GF562J	
R121	2	8.6k 25w	1JA7519H43	
R122	2	3.3k 2w	RC42GF332J	
R123	2	3.3k 2w	RC42GF332J	
R124	2	8.6k 25w	1JA7519H43	
R127	2	20k 1w	RC32GF203J	
R128	2	20k 1w	RC32GF203J	
R129	2	20k 1w	RC32GF203J	
R130	2	20k 1w	RC32GF203J	
R201	1	330k 1/2w	RC20GF334J	E-scope vert amp
R202	1	82k 1/2w	RC20GF823J	
R203	1	330k 1/2w	RC20GF334J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R204	1	100k 1/2w	RC20GF104J	E-scope vert amp
R205	1	110k 1/2w	RC20GF114J	
R206	1	39k 1/2w	RC20GF393J	
R207	1	7.5k 1w	RC32GF752J	
R208	1	3.3k 1/2w	RC20GF332J	
R209	1	7.5k 1w	RC32GF752J	
R210	1	110k 1/2w	RC20GF114J	
R211	1	39k 1/2w	RC20GF393J	
R212	1	680k 1/2w	RC20GF684J	
R213	1	1k 1/2w	RC20GF102J	
R214	1	2.7k 1/2w	RC20GF272J	
R215	1	2.7k 1/2w	RC20GF272J	
R216	1	100k 1/2w	RC20GF104J	
R217	1	100k 1/2w	RC20GF104J	
R218	1	75k 1/2w	RC20GF753J	
R219	1	1.5 meg 1/2w	RC20GF155J	
R220	1	100k 1/2w	RC20GF104J	
R221	1	20k 1/2w	RC20GF203J	
R222	1	1 meg 1/2w	RC20GF105J	
R223	1	51k 1/2w	RC20GF513J	
R224	1	10k 1/2w	RC20GF103J	
R225	1	18k 1/2w	RC20GF183J	
R226	1	120k 1/2w	RC20GF124J	
R227	1	1 meg 1/2w	RC20GF105J	
R228	1	470k 1/2w	RC20GF474J	
R229	1	22k 1/2w	RC20GF223J	
R231	1	100k 1/2w	RC20GF104J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R232	1	100k 1/2w	RC20GF104J	E-scope vert amp
R233	1	10k 1/2w	RC20GF103J	
R234	1	9.1k 1w	RC32GF912J	
R235	1	9.1k 1w	RC32GF912J	
R236	1	1 meg 1/2w	RC20GF105J	
R237	1	1 meg 1/2w	RC20GF105J	
R238	1	10k 1/2w	RC20GF103J	
R239	1	22k 1/2w	RC20GF223J	
R240	1	12k 2w	RC42GF123J	
R241	1	1 meg 1/2w	RC20GF105J	
R242	1	1 meg 1/2w	RC20GF105J	
R243	1	15k 1/2w	RC20GF153J	
R244	1	15k 1/2w	RC20GF153J	
R245	1	7.1k 5w	RW57G712	
R246	1	7.1k 5w	RW57G712	
R247	1	150 ohms 1/2w	RC20GF151J	
R248	1	150 ohms 1/2w	RC20GF151J	
R249	1	47k 1/2w	RC20GF473J	
R250	1	47k 1/2w	RC20GF473J	
R251	1	180k 1/2w	RC20GF184J	
R252	1	6.2 meg 1/2w	RC20GF625J	
R253	1	33k 1/2w	RC20GF333J	
R254	1	150k 1/2w	RC20GF154J	
R255	1	100k 1/2w	RC20GF104J	
R256	1	100k 1/2w	RC20GF104J	
R257	1	10k 1/2w	RC20GF103J	
R258	1	10k 1/2w	RC20GF103J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R259	1	1.3k 1/2w	RC20GF132J	E-scope vert amp
R260	1	7.5k 1w	RC32GF752J	
R261	1	180k 1/2w	RC20GF184J	
R262	1	750k 1/2w	RC20GF754J	
R263	1	1.5 meg 1/2w	RC20GF155J	
R264	1	10k 1/2w	RC20GF103J	
R265	1	150k 1/2w	RC20GF154J	
R266	1	560k 1/2w	RC20GF564J	
R267	1	47k 1w	RC32GF473J	
R268	1	47k 1w	RC32GF473J	
R269	1	10k 1/2w	RC20GF103J	
R270	1	1 meg 1/2w	RC20GF105J	
R271	1	47k 1w	RC32GF473J	
R272	1	1 meg 1/2w	RC20GF105J	
R273	1	180k 1/2w	RC20GF184J	
R274	1	24k 1/2w	RC20GF243J	
R275	1	47K 1/2w	RC20GF473J	
R276	1	15k 1/2w	RC20GF153J	
R277	1	15k 1/2w	RC20GF153J	
R278	1	4.7k 1/2w	RC20GF472J	
R279	1	47k 1/2w	RC20GF473J	
R280	1	3.3k 1/2w	RC20GF332J	
R281	1	1 meg 1/2w	RC20GF105J	
R282	1	1 meg 1/2w	RC20GF105J	
R283	1	1 meg 1/2w	RC20GF105J	
R284	1	1 meg 1/2w	RC20GF105J	
R285	1	680k 1/2w	RC20GF684J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R286	1	27k 1/2w	RC20GF273J	E-scope vert amp
R287	1	750k 1/2w	RC20GF754J	
R288	1	1k 1/2w	RC20GF102J	
R289	1	180k 1/2w	RC20GF184J	
R290	1	7.5k 1w	RC32GF752J	
R291	1	10k 1/2w	RC20GF103J	
R292	1	1.3k 1/2w	RC20GF132J	
R293	1	10k 1/2w	RC20GF103J	
R294	1	100k 1/2w	RC20GF104J	
R295	1	10k 1/2w	RC20GF103J	
R501	1	100 ohms 1/2w	RC20GF101J	E-scope hor amp
R502	1	110k 1/2w	RC20GF114J	
R503	1	18k 1/2w	RC20GF183J	
R504	1	10k 1w	RC32GF103J	
R505	1	10k 1w	RC32GF103J	
R506	1	2.2k 1/2w	RC20GF222J	
R507	1	110k 1/2w	RC20GF114J	
R508	1	18k 1/2w	RC20GF183J	
R509	1	470k 1/2w	RC20GF474J	
R510	1	510k 1/2w	RC20GF514J	
R511	1	5.1k 1/2w	RC20GF512J	
R512	1	15k 1/2w	RC20GF153J	
R513	1	1.2 meg 1/2w	RC20GF125J	
R514	1	100k 1/2w	RC20GF104J	
R515	1	100k 1/2w	RC20GF104J	
R516	1	100k 1/2w	RC20GF104J	
R517	1	10k 1/2w	RC20GF103J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R518	1	10k 1/2w	RC20GF103J	E-scope hor amp
R519	1	1.3k 1/2w	RC20GF132J	
R520	1	7.5k 1w	RC32GF752J	
R521	1	180k 1/2w	RC20GF184J	
R522	1	750k 1/2w	RC20GF754J	
R523	1	1.5 meg 1/2w	RC20GF155J	
R524	1	10k 1/2w	RC20GF103J	
R525	1	1.2 meg 1/2w	RC20GF125J	
R526	1	82k 1/2w	RC20GF823J	
R527	1	220k 1/2w	RC20GF224J	
R528	1	16k 1/2w	RC20GF163J	
R529	1	1k 1/2w	RC20GF102J	
R530	1	1 meg 1/2w	RC20GF105J	
R531	1	1k 1/2w	RC20GF102J	
R532	1	100k 1/2w	RC20GF104J	
R533	1	1k 1/2w	RC20GF102J	
R534	1	1 meg 1/2w	RC20GF105J	
R535	1	3 meg 1/2w	RC20GF305J	
R536	1	2.2k 1/2w	RC20GF222J	
R537	1	47k 1w	RC32GF473J	
R538	1	36k 1w	RC32GF363J	
R539	1	10k 1/2w	RC20GF103J	
R540	1	10k 1/2w	RC20GF103J	
R541	1	9.1k 1w	RC32GF912J	
R542	1	9.1k 1w	RC32GF912J	
R543	1	12k 2w	RC42GF123J	
R544	1	3.3k 1/2w	RC20GF332J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R545	1	56k 1/2w	RC20GF563J	E-scope hor amp
R546	1	10k 1/2w	RC20GF103J	
R547	1	6.2k 1/2w	RC20GF622J	
R548	1	1 meg 1/2w	RC20GF105J	
R549	1	1 meg 1/2w	RC20GF105J	
R550	1	160 ohms 1/2w	RC20GF161J	
R551	1	160 ohms 1/2w	RC20GF161J	
R552	1	10k 25w	1JA7519H10	
R553	1	10k 2w	RC42GF103J	
R554	1	15k 1/2w	RC20GF153J	
R555	1	33k 1/2w	RC20GF333J	
R556	1	100k 1/2w	RC20GF104J	
R601	1	22k 1/2w	RC20GF223J	Synch-ronizer
R602	1	10k 1/2w	RC20GF103J	
R603	1	10k 1/2w	RC20GF103J	
R604	1	5.1k 1/2w	RC20GF512J	
R605	1	22k 1/2w	RC20GF223J	
R606	1	10k 1/2w	RC20GF103J	
R607	1	7.5k 1/2w	RC20GF752J	
R608	1	3.6k 1/2w	RC20GF362J	
R609	1	10k 1/2w	RC20GF103J	
R610	1	100k 1/2w	RC20GF104J	
R611	1	5.1k 1/2w	RC20GF512J	
R612	1	10k 1/2w	RC20GF103J	
R613	1	10k 1/2w	RC20GF103J	
R614	1	5.1k 1/2w	RC20GF512J	
R615	1	100 ohms 1/2w	RC20GF101J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R616	1	100 ohms 1/2w	RC20GF101J	Synch-ronizer
R617	1	120k 1/2w	RC20GF124J	
R618	1	220k 1/2w	RC20GF224J	
R619	1	3.3k 1/2w	RC20GF332J	
R620	1	12k 1/2w	RC20GF123J	
R621	1	5.1k 1/2w	RC20GF512J	
R622	1	1k 1/2w	RC20GF102J	
R623	1	3.3k 1/2w	RC20GF332J	
R624	1	12k 1/2w	RC20GF123J	
R625	1	5.1k 1/2w	RC20GF512J	
R626	1	120k 1/2w	RC20GF124J	
R627	1	220k 1/2w	RC20GF224J	
R628	1	10k 1/2w	RC20GF103J	
R629	1	5.1k 1/2w	RC20GF512J	
R630	1	100 ohms 1/2w	RC20GF101J	
R631	1	10k 1/2w	RC20GF103J	
R632	1	220k 1/2w	RC20GF224J	
R633	1	120k 1/2w	RC20GF124J	
R634	1	5.1k 1/2w	RC20GF512J	
R635	1	12k 1/2w	RC20GF123J	
R636	1	3.3k 1/2w	RC20GF332J	
R637	1	820 ohms 1/2w	RC20GF821J	
R638	1	5.1k 1/2w	RC20GF512J	
R639	1	12k 1/2w	RC20GF123J	
R640	1	3.3k 1/2w	RC20GF332J	
R641	1	20k 1/2w	RC20GF203J	
R642	1	220k 1/2w	RC20GF224J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R643	1	120k 1/2w	RC20GF124J	Synch-ronizer
R644	1	220k 1/2w	RC20GF224J	
R645	1	3.3k 1/2w	RC20GF332J	
R646	1	120k 1/2w	RC20GF124J	
R647	1	5.1k 1/2w	RC20GF512J	
R648	1	12k 1/2w	RC20GF123J	
R649	1	820 ohms 1/2w	RC20GF821J	
R650	1	5.1k 1/2w	RC20GF512J	
R651	1	12k 1/2w	RC20GF123J	
R652	1	3.3k 1/2w	RC20GF332J	
R653	1	120k 1/2w	RC20GF124J	
R654	1	220k 1/2w	RC20GF224J	
R655	1	220k 1/2w	RC20GF224J	
R656	1	120k 1/2w	RC20GF124J	
R657	1	5.1k 1/2w	RC20GF512J	
R658	1	12k 1/2w	RC20GF123J	
R659	1	3.3k 1/2w	RC20GF332J	
R660	1	3.3k 1/2w	RC20GF332J	
R661	1	12k 1/2w	RC20GF123J	
R662	1	5.1k 1/2w	RC20GF512J	
R663	1	120k 1/2w	RC20GF124J	
R664	1	220k 1/2w	RC20GF224J	
R665	1	220k 1/2w	RC20GF224J	
R666	1	120k 1/2w	RC20GF124J	
R667	1	12k 1/2w	RC20GF123J	
R668	1	3.3k 1/2w	RC20GF332J	
R669	1	5.1k 1/2w	RC20GF512J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R670	1	3.3k 1/2w	RC20GF332J	Synch-ronizer
R671	1	56k 1/2w	RC20GF563J	
R672	1	1k 1/2w	RC20GF102J	
R673	1	5.1k 1/2w	RC20GF512J	
R674	1	12k 1/2w	RC20GF123J	
R675	1	120k 1/2w	RC20GF124J	
R676	1	220k 1/2w	RC20GF224J	
R677	1	220k 1/2w	RC20GF224J	
R678	1	5.1k 1/2w	RC20GF512J	
R679	1	120k 1/2w	RC20GF124J	
R680	1	12k 1/2w	RC20GF123J	
R681	1	3.3k 1/2w	RC20GF332J	
R682	1	3.3k 1/2w	RC20GF332J	
R683	1	1k 1/2w	RC20GF102J	
R684	1	5.1k 1/2w	RC20GF512J	
R685	1	12k 1/2w	RC20GF123J	
R686	1	120k 1/2w	RC20GF124J	
R687	1	220k 1/2w	RC20GF224J	
R688	1	220k 1/2w	RC20GF224J	
R689	1	5.1k 1/2w	RC20GF512J	
R690	1	120k 1/2w	RC20GF124J	
R691	1	12k 1/2w	RC20GF123J	
R692	1	3.3k 1/2w	RC20GF332J	
R693	1	3.3k 1/2w	RC20GF332J	
R694	1	1k 1/2w	RC20GF102J	
R695	1	5.1k 1/2w	RC20GF512J	
R696	1	12k 1/2w	RC20GF123J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R697	1	120k 1/2w	RC20GF124J	Synch-ronizer
R698	1	220k 1/2w	RC20GF224J	
R699	1	10k 1/2w	RC20GF103J	
R701	1	10k 1/2w	RC20GF103J	
R702	1	5.1k 1/2w	RC20GF512J	
R703	1	4.7k 1/2w	RC20GF422J	
R704	1	100 ohms 1/2w	RC20GF101J	
R705	1	100k 1/2w	RC20GF104J	
R706	1	300 ohms 1/2w	RC20GF301J	
R707	1	1.3k 1/2w	RC20GF132J	
R708	1	47 ohms 1/2w	RC20GF470J	
R709	1	10k 1/2w	RC20GF103J	
R710	1	100k 1/2w	RC20GF104J	
R711	1	300 ohms 1/2w	RC20GF301J	
R712	1	1.3k 1/2w	RC20GF132J	
R713	1	47 ohms 1/2w	RC20GF470J	
R714	1	10k 1/2w	RC20GF103J	
R715	1	197k 1/2w	1JA8691H49	
R716	1	100k 1/2w	RC20GF104J	
R717	1	7.5k 1w	RC32GF752J	
R718	1	47 ohms 1/2w	RC20GF470J	
R719	1	1.3k 1/2w	RC20GF132J	
R720	1	15k 1/2w	RC20GF153J	
R721	1	1 meg 1/2w	RC20GF105J	
R722	1	47k 1/2w	RC20GF473J	
R723	1	470k 1/2w	RC20GF474J	
R724	1	100k 1/2w	RC20GF104J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R725	1	220 ohms 1/2w	RC20GF221J	Synch-ronizer
R726	1	1.8k 1/2w	RC20GF182J	
R727	1	10k 1/2w	RC20GF103J	
R728	1	100k 1/2w	RC20GF104J	
R729	1	100k 1/2w	RC20GF104J	
R730	1	5.1k 1/2w	RC20GF512J	
R731	1	5.1k 1/2w	RC20GF512J	
R732	1	300k 1/2w	RC20GF304J	
R733	1	43k ± 1% 1/2w	1JA7897H71	
R734	1	10k 1/2w	RC20GF103J	
R735	1	10k 1/2w	RC20GF103J	
R736	1	10k 1/2w	RC20GF103J	
R737	1	100k 1/2w	RC20GF104J	
R738	1	27k 1/2w	RC20GF273J	
R739	1	1 meg 1/2w	RC20GF105J	
R740	1	1k 1/2w	RC20GF102J	
R741	1	10k 1/2w	RC20GF103J	
R742	1	100k 1/2w	RC20GF104J	
R743	1	10k 1w	RC32GF103J	
R744	1	197k 1/2w	1JA8691H49	
R745	1	7.5k 1w	RC32GF752J	
R746	1	1.3k 1/2w	RC20GF132J	
R747	1	100k 1/2w	RC20GF104J	
R748	1	100k 1/2w	RC20GF104J	
R749	1	10k 1/2w	RC20GF103J	
R750	1	100k 1/2w	RC20GF104J	
R751	1	1.3k 1/2w	RC20GF132J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R752	1	10k 1w	RC32GF103J	Synch-ronizer
R753	1	100k 1/2w	RC20GF104J	
R754	1	7.5k 1w	RC32GF752J	
R755	1	100k 1/2w	RC20GF104J	
R756	1	100k 1/2w	RC20GF104J	
R757	1	10k ± 1% 1/2w	1JA8691H68	
R758	1	62k 1/2w	RC20GF623J	
R759	1	100k 1/2w	RC20GF104J	
R760	1	5.6k 1w	RC32GF562J	
R761	1	197k 1/2w	1JA8691H49	
R762	1	1.8k 1/2w	RC20GF182J	
R763	1	33k 1/2w	RC20GF333J	
R764	1	1k 1/2w	RC20GF102J	
R765	1	1k 1/2w	RC20GF102J	
R766	1	3.3k 1/2w	RC20GF332J	
R767	1	27k 1w	RC32GF273J	
R768	1	24k 1/2w	RC20GF243J	
R769	1	8.2k 1/2w	RC20GF822J	
R770	1	10k 1/2w	RC20GF103J	
R771	1	100k 1/2w	RC20GF104J	
R772	1	3.9k 1/2w	RC20GF392J	
R773	1	197k 1/2w	1JA8691H49	
R774	1	7.5k 1w	RC32GF752J	
R775	1	22k ± 1% 1/2w	1JA8691H56	
R776	1	1.3k 1/2w	RC20GF132J	
R777	1	62k 1/2w	RC20GF623J	
R778	1	22k 1/2w	RC20GF223J	

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REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R779	1	1k 1/2w	RC20GF102J	Synch-ronizer
R780	1	820 ohms 1/2w	RC20GF821J	
R781	1	82 ohms 1/2w	RC20GF820J	
R782	1	3.3k 1/2w	RC20GF332J	
R783	1	27k 1w	RC32GF273J	
R784	1	100k 1/2w	RC20GF104J	
R785	1	62k 1/2w	RC20GF623J	
R786	1	100k 1/2w	RC20GF104J	
R787	1	100k 1/2w	RC20GF104J	
R788	1	5.1k 1/2w	RC20GF512J	
R789	1	197k 1/2w	1JA8691H49	
R790	1	1.8k 1/2w	RC20GF182J	
R791	1	5.6k 1w	RC32GF562J	
R792	1	68k 1/2w	RC20GF683J	
R793	1	100k 1/2w	RC20GF104J	
R794	1	100k 1/2w	RC20GF104J	
R795	1	100k 1/2w	RC20GF104J	
R796	1	22k 1/2w	RC20GF223J	
R797	1	197k 1/2w	1JA8691H49	
R798	1	1.8k 1/2w	RC20GF182J	
R799	1	5.6k 1w	RC32GF562J	
R801	1	680 ohms 1/2w	RC20GF681J	
R802	1	3.3k 1/2w	RC20GF332J	
R803	1	62k 1/2w	RC20GF623J	
R804	1	100k 1/2w	RC20GF104J	
R805	1	620k 1/2w	RC20GF624J	
R806	1	5.1k 1/2w	RC20GF512J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R807	1	15k 1/2w	RC20GF153J	Synch-ronizer
R808	1	1 meg 1/2w	RC20GF105J	
R809	1	620k 1/2w	RC20GF624J	
R810	1	1 meg 1/2w	RC20GF105J	
R811	1	22k 1/2w	RC20GF223J	
R812	1	36k 1/2w	RC20GF363J	
R813	1	91k 1/2w	RC20GF913J	
R814	1	100k 1/2w	RC20GF104J	
R815	1	1.8k 1/2w	RC20GF182J	
R816	1	3k 1/2w	RC20GF302J	
R817	1	197k 1/2w	1JA8691H49	
R818	1	1.8k 1/2w	RC20GF182J	
R819	1	5.6k 1w	RC32GF562J	
R821	1	3.3k 1/2w	RC20GF332J	
R822	1	3.3k 1/2w	RC20GF332J	
R823	1	12k 1/2w	RC20GF123J	
R824	1	12k 1/2w	RC20GF123J	
R825	1	120k 1/2w	RC20GF124J	
R826	1	120k 1/2w	RC20GF124J	
R827	1	220k 1/2w	RC20GF224J	
R828	1	220k 1/2w	RC20GF224J	
R829	1	5.1K 1/2w	RC20GF512J	
R830	1	5.1k 1/2w	RC20GF512J	
R831	1	1k 1/2w	RC20GF102J	
R832	1	22k 1/2w	RC20GF223J	
R833	1	22k 1/2w	RC20GF223J	
R834	1	10k 1/2w	RC20GF103J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R835	1	5.1k 1/2w	RC20GF512J	Synch-ronizer
R836	1	100k 1/2w	RC20GF104J	
R837	1	100k 1/2w	RC20GF104J	
R838	1	1.5k 1/2w	RC20GF152J	
R839	1	18k 1/2w	RC20GF183J	
R840	1	100k 1/2w	RC20GF104J	
R841	1	10 meg 1/2w	RC20GF106J	
R1201	1	8.9k ± 1%	1JA7896H192	Trans-rec
R1202	1	1k 1/2w	RC20GF102J	
R1221	1	3.3 meg 1w	RC32GF335J	
R1222	1	3 meg	RC32GF305J	
R1223	1	100k 1/2w	RC20GF104J	
R1224	1	Variable 100k 1/2w	2JC2779H45	
R1226	1	100 ohms 1/2w	RC20GF101J	
R1227	1	100 ohms 1/2w	RC20GF101J	
R1228	1	100 ohms 1/2w	RC20GF101J	
R1229	1	100 ohms 1/2w	RC20GF101J	
R1401	1	100 ohms 1/2w	RC20GF101J	Preamp
R1402	1	100 ohms 1/2w	RC20GF101J	
R1403	1	150 ohms 1/2w	RC20GF151J	
R1404	1	270 ohms 1/2w	RC20GF271J	
R1405	1	150 ohms 1/2w	RC20GF151J	
R1406	1	270 ohms 1/2w	RC20GF271J	
R1407	1	5.6k 1/10w	2JC2718H02	
R1408	1	270 ohms 1/2w	RC20GF271J	
R1409	1	270 ohms 1/2w	RC20GF271J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R1410	1	5.6k 1/10w	2JC2718H02	Preamp
R1411	1	270 ohms 1/2w	RC20GF271J	
R1412	1	270 ohms 1/2w	RC20GF271J	
R1601	1	91 ohms 1/2w	RC20GF910J	Postamp
R1602	1	270 ohms 1/2w	RC20GF271J	
R1603	1	270 ohms 1/2w	RC20GF271J	
R1604	1	2.2k 1/10w	2JC2718H17	
R1605	1	270 ohms 1/2w	RC20GF271J	
R1606	1	270 ohms 1/2w	RC20GF271J	
R1607	1	2.7k 1/10w	2JC2718H19	
R1608	1	270 ohms 1/2w	RC20GF271J	
R1609	1	270 ohms 1/2w	RC20GF271J	
R1610	1	2.2k 1/10w	2JC2718H17	
R1611	1	270 ohms 1/2w	RC20GF271J	
R1612	1	270 ohms 1/2w	RC20GF271J	
R1613	1	3.9k 1/2w	RC20GF392J	
R1614	1	6.8k 1w	RC32GF682J	
R1615	1	1k 1/2w	RC20GF102J	
R1616	1	120 ohms 1/2w	RC20GF121J	
R1617	1	470 ohms 1/2w	RC20GF471J	
R1618	1	47k 1/2w	RC20GF473J	
R1619	1	150k 1/2w	RC20GF154J	
R1620	1	Variable 1k 1/2w	1JC4841H04	
R1621	1	Variable 250k 1/2w	1JC4841H11	
R1622	1	Variable 1k 1/2w	1JC4841H04	
R1623	1	3.3k 1/10w	2JC2718H20	
R1801	1	430 ohms 1/2w	RC20GF431J	AFC-IF
R1802	1	2k 1/10w	2JC2718H23	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R1803	1	430 ohms 1/2w	RC20GF431J	AFC-IF
R1804	1	2.4k 1/10w	2JC2718H18	
R1805	1	430 ohms 1/2w	RC20GF431J	
R1806	1	2.7k 1/10w	2JC2718H19	
R1807	1	6.8k 1/10w	2JC2718H38	
R1808	1	120k 1/2w	RC20GF124J	
R1809	1	6.8k 1/10w	2JC2718H38	
R1810	1	36k 1/2w	RC20GF363J	
R1811	1	36k 1/2w	RC20GF363J	
R1812	1	3.9k 1/2w	RC20GF392J	
R1813	1	11k 1/2w	RC20GF113J	
R1814	1	180k 1/2w	RC20GF184J	
R1815	1	11k 1/2w	RC20GF113J	
R1816	1	220 ohms 1/2w	RC20GF221J	
R1817	1	5.1 meg 1/10w	2JC2718H37	
R1818	1	3.3 meg 1/10w	2JC2718H08	
R1819	1	1.8 meg 1/2w	RC20GF185J	
R1820	1	470k 1/2w	RC20GF474J	
R1821	1	47k 1w	RC32GF473J	
R1822	1	10k 1/2w	RC20GF103J	
R1823	1	1k 1/2w	RC20GF102J	
R1829	1	33k 1/10w	2JC2718H33	
R2001	2	3k 1/2w	RC20GF302J	X-scope
R2002	2	3k 1/2w	RC20GF302J	
R2003	2	3k 1/2w	RC20GF302J	
R2004	2	3k 1/2w	RC20GF302J	
R2005	2	3k 1/2w	RC20GF302J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R2006	2	3k 1/2w	RC20GF302J	X-scope
R2007	2	3k 1/2w	RC20GF302J	
R2008	2	24k 1/2w	RC20GF243J	
R2009	2	10k 1/2w	RC20GF103J	
R2010	2	Variable 2.5k 1/2w	2JC2779H62	
R2011	2	Variable 10k 1/2w	2JC2779H42	
R2012	2	Variable 50k 1/2w	2JC2779H44	
R2013	2	100k 1/2w	RC20GF104J	
R2014	2	Variable 50k 1/2w	2JC2779H44	
R2015	2	51k 1/2w	RC20GF513J	
R2016	2	Variable 25k 1/2w	2JC2779H43	
R2017	2	Variable 10k 1/2w	2JC2779H42	
R2018	2	Variable 100k 1/2w	2JC2779H45	
R2019	2	18k 2w	RC42GF183J	
R2020	2	43k 2w	RC42GF433J	
R2021	2	51k 1/2w	RC20GF513J	
R2022	2	5.1k 1/2w	RC20GF512J	
R2023	2	510k 1/2w	RC20GF514J	
R2024	2	100k 1/2w	RC20GF104J	
R2025	2	100k 1/2w	RC20GF104J	
R2026	2	Variable 100k	2JC2963H01	
R2027	2	Variable 100k	2JC2963H01	
R2028	2	Variable 100k	2JC2963H01	
R2029	2	62k 1/2w	RC20GF623J	
R2030	2	100k 1/2w	RC20GF104J	
R2031	2	Variable 5k 2w	1JC1503H04	
R2032	2	20k 1/2w	RC20GF203J	
R2033	2	43k 2w	RC42GF433J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R2034	2	1 meg 1/2w	RC20GF105J	X-scope
R2035	2	100k 1/2w	RC20GF104J	
R2036	2	100k 1/2w	RC20GF104J	
R2037	2	1.8k 1/2w	RC20GF182J	
R2038	2	130k 1/2w	RC20GF134J	
R2039	2	1 meg 1/2w	RC20GF105J	
R2201	1	Variable 50k	See note 3 on 703R134	E-scope
R2202	1	3.3k 1/2w	RC20GF332J	
R2203	1	43k 1/2w	RC20GF433J	
R2204	1	Variable 100k	2JC2779H45	
R2205	1	27k 1/2w	RC20GF273J	
R2206	1	100k 1/2w	RC20GF104J	
R2207	1	Variable 25k	2JC2779H43	
R2208	1	110k 1/2w	RC20GF114J	
R2209	1	Variable 250k	2JC2779H46	
R2210	1	10 meg 1/2w	RC20GF106J	
R2211	1	10 meg 1/2w	RC20GF106J	
R2212	1	Variable, dual 250k	1JA3363H06	
R2213	1	1 meg 1/2w	RC20GF105J	
R2214	1	1 meg 1/2w	RC20GF105J	
R2215	1	Variable 100 ohms	RP103R0101KK	
R2216	1	Variable, dual 250k	1JA3363H06	
R2217	1	Variable, dual 100k	See Note 2 on 703R134	
R2218	1	62k ± 1% 1/2w	1JA8691H18	
R2219	1	50k ± 1% 1/2w	1JA8691H38	
R2220	1	Variable, dual 10k	2JC2380H24	
R2221	1	10 meg 1/2w	RC20GF106J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R2801	1	510 ohms 1/2w	RC20GF511J	Power supply
R2802	1	510 ohms 1/2w	RC20GF511J	
R2803	1	510 ohms 1/2w	RC20GF511J	
R2804	1	510 ohms 1/2w	RC20GF511J	
R2806	1	27 ohms 2w	RC42GF270J	
R2807	1	27 ohms 2w	RC42GF270J	
R2808	1	27 ohms 2w	RC42GF270J	
R2809	1	27 ohms 2w	RC42GF270J	
R2810	1	Variable 100k 1/2w	2JC2779H45	
R2811	1	Variable 30k 1w	RC32GF303J	
R2812	1	510 ohms 1/2w	RC20GF511J	
R2813	1	510 ohms 1/2w	RC20GF511J	
R2814	1	390k 1w	RC32GF394J	
R2815	1	1k 1w	RC32GF102J	
R2816	1	510 ohms 1/2w	RC20GF511J	
R2817	1	510 ohms 1/2w	RC20GF511J	
R2818	1	510 ohms 1/2w	RC20GF511J	
R2819	1	510 ohms 1/2w	RC20GF511J	
R2820	1	27 ohms 2w	RC42GF270J	
R2821	1	27 ohms 2w	RC42GF270J	
R2822	1	27 ohms 2w	RC42GF270J	
R2823	1	27 ohms 2w	RC42GF270J	
R2824	1	75k ± 1% 3/4w	1JA7896H45	
R2825	1	Variable 10k 1 1/2w	2JC2380H19	
R2826	1	33k ± 1% 3/4w	1JA7896H138	
R2827	1	510 ohms 1/2w	RC20GF511J	
R2828	1	510 ohms 1/2w	RC20GF511J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R2829	1	1k 1w	RC32GF102J	Power supply
R2830	1	6.5k 2w	1JC8132H41	
R2831	1	6.5k 2w	1JC8132H41	
R2832	1	510 ohms 1/2w	RC20GF511J	
R2833	1	510 ohms 1/2w	RC20GF511J	
R2834	1	510 ohms 1/2w	RC20GF511J	
R2835	1	510 ohms 1/2w	RC20GF511J	
R2836	1	27 ohms 2w	RC42GF270J	
R2837	1	27 ohms 2w	RC42GF270J	
R2838	1	27 ohms 2w	RC42GF270J	
R2839	1	27 ohms 2w	RC42GF270J	
R2840	1	510 ohms 1/2w	RC20GF511J	
R2841	1	510 ohms 1/2w	RC20GF511J	
R2842	1	27 ohms 2w	RC42GF270J	
R2843	1	27 ohms 2w	RC42GF270J	
R2844	1	200k ± 1% 3/4w	1JA7897H37	
R2845	1	Variable 10k ± 1% 0.8w	575R312H10	
R2846	1	3k ± 1% 1/2w	1JA8691H109	
R2847	1	330k ± 1% 1/2w	1JA8691H78	
R2848	1	200k ± 1% 3/4w	1JA7897H37	
R2849	1	10k ± 1% 1/4w	1JA7878H61	
R2850	1	131k ± 1% 1.2w	1JA8196H18	
R2851	1	131 ± 1% 1.2w	1JA8196H18	
R2852	1	10k ± 1% 1/4w	1JA7878H61	
R2853	1	135k ± 1% 3/4w	1JA7897H62	
R2854	1	135k ± 1% 3/4w	1JA7897H62	
R2855	1	10k ± 1% 1/4w	1JA7878H61	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R2856	1	135k ± 1% 3/4w	1JA7897H62	Power supply
R2857	1	135k ± 1% 3/4w	1JA7897H62	
R2858	1	10k ± 1% 1/4w	1JA7878H61	
R2859	1	50k ± 1% 1/2w	1JA8691H60	
R2860	1	135k ± 1% 3/4w	1JA7897H62	
R2861	1	135 ± 1% 3/4w	1JA7897H62	
R2862	1	100k ± 1% 1/2w	1JA8691H13	
R2863	1	Variable 10k ± 1% .8w	575R312H10	
R2864	1	3k ± 1% 1/2w	1JA8691H109	
R2865	1	100k ± 1% 1/4w	1JA7878H05	
R2866	1	100k ± 1% 1/4w	1JA7878H05	
R2867	1	10k ± 1% 1/4w	1JA7878H61	
R2868	1	6.5k ± 1% 2w	1JC8132H41	
R2869	1	6.5k ± 1% 2w	1JC8132H41	
R2870	1	6.5 ± 1% 2w	1JC8132H41	
R2871	1	10k ± 1% 1/4w	1JA7878H61	
R2872	1	4.7k ± 1% 1/4w	1JA7878H72	
R2873	1	20k ± 1% 3/4w	1JA7897H04	
R2874	1	10k ± 1% 1/4w	1JA7878H61	
R2875	1	4.7 ± 1% 1/4w	1JA7878H72	
R2876	1	20k ± 1% 3/4w	1JA7897H04	
R2877	1	10k ± 1% 1/4w	1JA7878H61	
R2878	1	50k ± 1% 1/2w	1JA8691H60	
R2879	1	62k ± 1% 3/4w	1JA7897H27	
R2880	1	75k ± 1% 3/4w	1JA7897H36	
R2881	1	100k ± 1% 1/2w	1JA8691H13	
R2882	1	Variable 10k ± 1% 0.8w	575R312H10	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R2883	1	3k ± 1% 1/2w	1JA8691H109	Power supply
R2884	1	100k ± 1% 1/4w	1JA7878H05	
R2885	1	100k ± 1% 1/4w	1JA7878H05	
R2886	1	10k ± 1% 1/4w	1JA7878H61	
R2887	1	6.5k ± 1% 2w	1JC8132H41	
R2888	1	6.5k ± 1% 2w	1JC8132H41	
R2889	1	6.5k ± 1% 2w	1JC8132H41	
R2890	1	10k ± 1% 1/4w	1JA7878H61	
R2891	1	4.7k ± 1% 1/4w	1JA7878H72	
R2892	1	20k ± 1% 3/4w	1JA7897H04	
R2893	1	10k ± 1% 1/4w	1JA7878H61	
R2894	1	4.7k ± 1% 1/4w	1JA7878H72	
R2895	1	20k ± 1% 3/4w	1JA7897H04	
R2896	1	10k ± 1% 1/4w	1JA7878H61	
R2897	1	50k ± 1% 1/2w	1JA8691H60	
R2898	1	62k ± 1% 3/4w	1JA7897H27	
R2899	1	75k ± 1% 3/4w	1JA7897H36	
R2901	1	200k ± 1% 3/4w	1JA7897H37	
R2902	1	Variable 10k ± 1% 0.8w	575R312H10	
R2903	1	3k ± 1% 1/2w	1JA8691H109	
R2904	1	330k ± 1% 1/2w	1JA8691H78	
R2905	1	200k ± 1% 3/4w	1JA7897H37	
R2906	1	10k ± 1% 1/4w	1JA7878H61	
R2907	1	131k ± 1% 1.2w	1JA8196H18	
R2908	1	131k ± 1% 1.2w	1JA8196H18	
R2909	1	10k ± 1% 1/4w	1JA7878H61	
R2910	1	135 ± 1% 3/4w	1JA7897H62	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R2911	1	135k ± 1% 3/4w	1JA7897H62	Power supply
R2912	1	10k ± 1% 1/4w	1JA7878H61	
R2913	1	135k ± 1% 3/4w	1JA7897H62	
R2914	1	135k ± 1% 3/4w	1JA7897H62	
R2915	1	10k ± 1% 1/4w	1JA7878H61	
R2916	1	50k ± 1% 1/2w	1JA8691H60	
R2917	1	135k ± 1% 3/4w	1JA7897H62	
R2918	1	135k ± 1% 3/4w	1JA7897H62	
R2919	1	131k ± 1% 1.2w	1JA8196H18	
R2920	1	131k ± 1% 1.2w	1JA8196H18	
R3201	1	10 meg	1JC7829H04	Modulator
R3202	1	Variable 2500 ohms 1/2w	2JC2779H62	
R3203	1	510 ohms 1w	RC32GF511J	
R3204	1	10k 2w	RC42GF103J	
R3205	1	100k 1/2w	RC20GF104J	
R3206	1	100 ohms 1/2w	RC20GF101J	
R3207	1	5.1k 2w	RC42GF512J	
R3208	1	1k 2w	RC42GF102J	
R3209	1	140 ohms 5w	RW55G141	
R3210	1	10 ohms 1/2w	RC20GF100J	
R3211	1	100k 1/2w	RC20GF104J	
R3212	1	100k 1/2w	RC20GF104J	
R3213	1	100k 1/2w	RC20GF104J	
R3214	1	1 meg 1/2w	RC20GF105J	
R3215	1	2k 1/2w	RC20GF202J	
R3401	1	10k ± 1% 1/2w	1JA8691H68	Synch-ronizer

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
RESISTORS (Continued)				
R3402	1	Variable 5k 1.5w	2JC2380H18	Synchronizer
R3403	1	Variable 5k 1.5w	2JC2380H18	
R3404	1	3.3k ± 1% 1/2w	1JA8691H98	
R3405	1	Variable 10k 1.5w	2JC2380H19	
R3406	1	Variable 5k 1.5w	2JC2380H18	
R3407	1	Variable 10k 1.5w	2JC2380H19	
R3408	1	Variable 5k 1.5w	2JC2380H18	
R3409	1	Variable 5k 1.5w	2JC2380H18	
R3410	1	2.7k 1/2w	RC20GF272J	
R3411	1	62k 1/2w	RC20GF623J	
R3801	1	187.4k ± .5% 1/2w	Cinema Eng. Co. No. 246E, 187k 1/2w	Control panel
R3802	1	375k ± .5% 3/4w	No. 247E, 375k 1/2w	
R3803	1	28k ± .5% 1/2w	No. 246E, 28k 1/2w	
R3804	1	187.4k ± .5% 1/2w	No. 246E, 187k 1/2w	
R3805	1	375k ± .5% 3/4w	No. 247E, 375k 1/2w	
R3806	1	500k ± .5% 1w	No. 254E, 500k 1w	
R3807	1	Variable 100k 2w	1JA3337H13	
R3808	1	5.1k 1w	RC32GF512J	
R3809	1	5.1k 1w	RC32GF512J	
R3810	1	5.1k 1w	RC32GF512J	
R4001	1	Variable 100k 1/2w	2JC2779H27	Antenna jct box
R4002	1	100k 1w	RC32GF104J	
R4003	1	20k 1w	RC32GF203J	
R4004	1	1 meg 1/2w	RC20GF105J	
R4005	1	240k 1/2w	RC20GF244J	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		RESISTORS (Continued)		
R4006	1	10k 1w	RC32GF103J	Antenna jct box
R4007	1	10k 1w	RC32GF103J	
R4008	1	100k 1/2w	RC20GF104J	
R4009	1	100k 1/2w	RC20GF104J	
R4010	1	1k 1w	RC32GF102J	
R4011	1	5.6k 1w	RC32GF562J	
R4012	1	100 ohms 1w	RC32GF101J	
R4013	1	43k 1w	RC32GF433J	
R4014 thru 4016	1	Variable, 2 gang 5k, 12.5k	Kendick Mfg. Co. (Special order)	
R4017	1	1k 1w	RC32GF102J	
R4018	1	75k 1w	RC32GF753J	
R4019	1	10k 1w	RC32GF103J	
R4020	1	1 meg 1/2w	RC20GF105J	
R4021	1	120k 1/2w	RC20GF124J	
R4022	1	Variable 1k 2w	575R186H04	Antenna
R4023	1	1k 1w	RC32GF102J	Antenna jct box
R4024	1	75k 1w	RC32GF753J	
R4025	1	75k 1w	RC32GF753J	
		SWITCHES		
S1201	1	Interlock	1JA3842H01	Trans-rec
S1202	1	Pressure interlock Robertshaw Fulton	Model No. 65MX122	
S1223	1	DPDT	2JC2914H01	
S2201	1		AN3021-1	E-scope

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		SWITCHES (Continued)		
S3201	1	Interlock	1JA3842H01	Modulator
S3401	1		703R165H01	Synch-ronizer
S3801	1		Oak Mfg Co 86336-F2C	Control panel
S3802	1		Oak Mfg Co 92134-N4C	
S3803	1		1JB2373H13	
S3804	1		1JB2373H11	
S3805	1		1JB6144H02	
S3806	1		Oak Mfg Co 86338-F1C	
S4001	1	Pressure interlock	Meletron Corp 417E-31-77	Antenna
S4002	1	SPST	1JA4280H02	
S4003 and S4004	1	DPDT sensitive switch	Micro-switch DT-2RV3-A7	
S4005	1	DPDT sensitive switch	Unimax 2DHBTX-1	
		TRANSFORMERS		
T601	1		Valor Electronics Co 02LA421	Synch-ronizer
T602	1		Valor Electronics Co 02LA421	
T603	1		United Transformer Co H-49	
T604	1		United Transformer Co H-50	
T1201	1	Filament	595R252H01	Trans-rec

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		TRANSFORMERS (Continued)		
T1202	1	High voltage pulse	595R263H01	Trans-rec
T1221	1	Filament	2JB1542H01	
T1401	1		595R410G01	Preamp
T1402	1		575R265H29	
T1403	1		575R265H03	
T1404	1		575R265H01	
T1405	1		575R265H31	
T1601	1		575R265H03	Postamp
T1602	1		575R265H01	
T1603	1		575R265H03	
T1604	1		575R265H01	
T1801	1	(See Note 3 on 703R122)	2JB2118G02	AFC-IF
T1802	1		2JC2706H07	
T1803	1		2JC2706H04	
T1804	1		2JC2706H05	
T2001	2		2JB1546H01	X-scope
T2002	2		2JB1531H01	
T2201	1		2JB1546H01	E-scope
T2202	1		2JB1531H01	
T2801	1		CE7M1	Power supply
T2802	1		1JC6965H01	
T2803	1		1JC6985H01	
T2804	1		1JC6965H01	
T2805	1		1JC6985H01	
T2806	1		1JC6985H01	
T3201	1		L-CE7H3	Modulator
T3202	1		595R251H01	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		TRANSFORMERS (Continued)		
T3203	1		1JB6329H01	Modulator
T3401	1		2JB1531H01	Synch-ronizer
T4001	1		United Transformer Co H54	Antenna jct box
T4002	1		Thordarson T21F08	
T4003	1		United Transformer Co H49	
		ELECTRON TUBES		
V1	2		6111	X-scope sweep amp
V2	2		6021	
V3	2		5702WA	
V4	2		5702WA	
V5	2		5702WA	
V6	2		6111	
V7	2		5687WA	
V8	2		6111	
V10	2		6112	
V11	2		6111	
V12	2		6111	
V13	2		5902	
V14	2		6021	
V15	2		6111	
V16	2		5702WA	
V17	2		5702WA	
V18	2		6111	
V19	2		5687WA	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		ELECTRON TUBES (Continued)		
V201	1		6111	E-scope vert amp
V202	1		6021	
V203	1		5703WA	
V204	1		6021	
V205	1		5702WA	
V206	1		5702WA	
V207	1		5902	
V208	1		5902	
V209	1		5784WA	
V210	1		6111	
V211	1		6021	
V212	1		6021	
V213	1		6111	
V214	1		5784WA	
V215	1		5784WA	
V216	1		6111	
V217	1		6021	
V218	1		5703WA	
V501	1		6021	E-scope hor amp
V502	1		5784WA	
V503	1		6021	
V504	1		6021	
V505	1		6021	
V506	1		6021	
V507	1		5702WA	
V508	1		5702WA	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		ELECTRON TUBES (Continued)		
V509	1		5902	E-scope hor amp
V510	1		5902	
V601	1		5702WA	Synch-ronizer
V602	1		5702WA	
V603	1		5784WA	
V604	1		5702WA	
V605	1		6021	
V606	1		6021	
V607	1		6111	
V608	1		6021	
V609	1		6111	
V610	1		6111	
V611	1		6021	
V612	1		6021	
V613	1		6021	
V614	1		6111	
V615	1		6111	
V616	1		5784WA	
V617	1		6111	
V1201	1	Magnetron	Microwave Assoc Model MA207	Trans-rec
V1202	1	Spark Cap	Bendix Aviation TG36	
V1221	1	ATR	2JC2341H01	
V1222	1	TR 6545	2JC2340H01	
V1223	1	Klystron	2JC2339H01	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
ELECTRON TUBES (Continued)				
V1401	1		5718A	Preamp
V1402	1		5718A	
V1403	1		6205	
V1404	1		6205	
V1601	1		6205	Postamp
V1602	1		6205	
V1603	1		6205	
V1604	1		6205	
V1605	1		6111	
V1801	1		5840	AFC-IF
V1802	1		5840	
V1803	1		5840	
V1804	1		6112	
V1805	1		6111	
V1806	1		6111	
V1807	1		5784WA	
V2001	2	Cathode ray tube	RCA C73703B	X-scope
V2201	1	Cathode ray tube	5UP7	E-scope
V2801	1	6336A	575R103H01	Power supply
V2802	1	6336A	575R103H01	
V2803	1		5783WA	
V2804	1		6080WA	
V2805	1	6336A	575R103H01	
V2806	1	6336A	575R103H01	
V2807	1		6080WA	
V2808	1	6336A	575R103H01	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		ELECTRON TUBES (Continued)		
V2809	1	6336A	575R103H01	Power supply
V2810	1	6336A	575R103H01	
V2811	1		6112	
V2812	1		5702WA	
V2813	1		5702WA	
V2814	1		6112	
V2815	1		6112	
V2816	1		5702WA	
V2817	1		5702WA	
V2818	1		5702WA	
V2819	1		6112	
V2820	1		5702WA	
V2821	1		5702WA	
V2822	1		5702WA	
V2823	1		6112	
V2824	1		5702WA	
V2825	1		5702WA	
V2826	1		6112	
V3201	1		5956	Modulator
V3202	1		5687WA	
V3203	1		6112	
V4001	1		6111	Antenna jct box
V4002	1		6111	
V4003	1		6111	

REF DESIG	QTY PER EQUIP	DESCRIPTION	DRAWING OR MFR. NO.	MAJOR COMPONENT
		MISCELLANEOUS ITEMS		
Y601	1	Crystal 81.94 KC	2JC2807H01	Synch-ronizer
Z1221	1	Power Supply	AMP Inc 851094	Trans-rec
Z1401	1	Heater choke	595R405G01	Preamp
Z1402	1	Heater choke	595R405G01	
Z1403	1	Heater choke	595R405G01	
Z1404	1	Balanced mixer	2JC2916H01	
Z1601 thru Z1604	4	Choke, Heater	595R405G01	Postamp
Z1801	1	Mixer	2JC2916H01	AFC-IF
Z1802 thru Z1807	6	Heater choke	2JA5452G01	
Z2001	2	Power supply, - 2kv	AMP Inc 851099	X-scope
Z2002	2	Bleeder	AMP Inc 4052	
Z2003	2	Power supply +10 kv	AMP Inc 851100	
Z2201	1	Power supply, 2kv	AMP Inc 851100	E-scope
Z2202	1	Bleeder	AMP Inc 850002	
Z3201	1	Pulse forming network	AMP Inc PS4080A	Modulator
E4001	1	Magnetic pickup	Electro-Products Lab 3030	Antenna
E4002	1	Hydraulic control valve	Moog Valve Co Inc 21-132	
BT4001	1	9-volt battery	RCA VS305	

SECTION V

SCHEMATIC DIAGRAMS

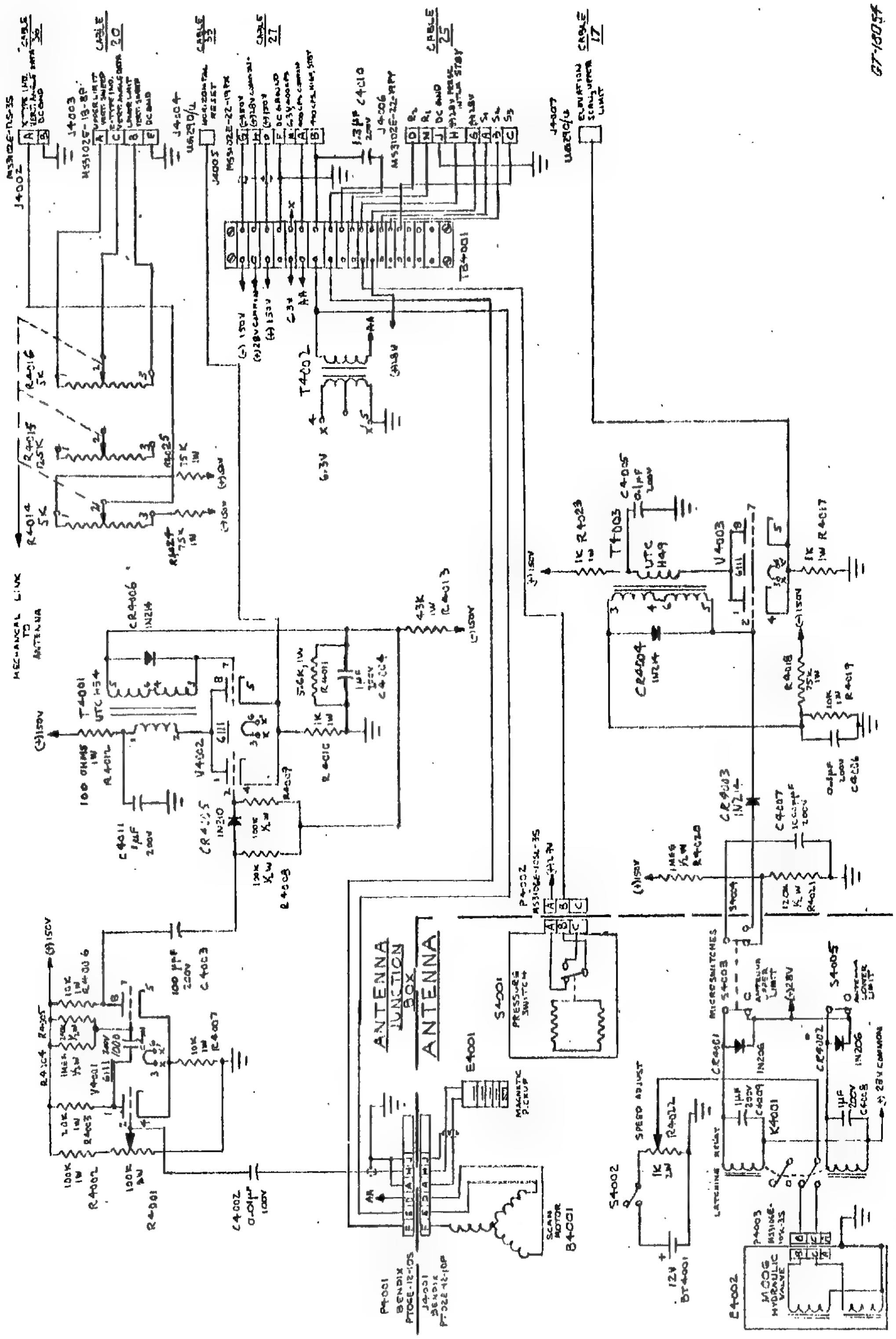
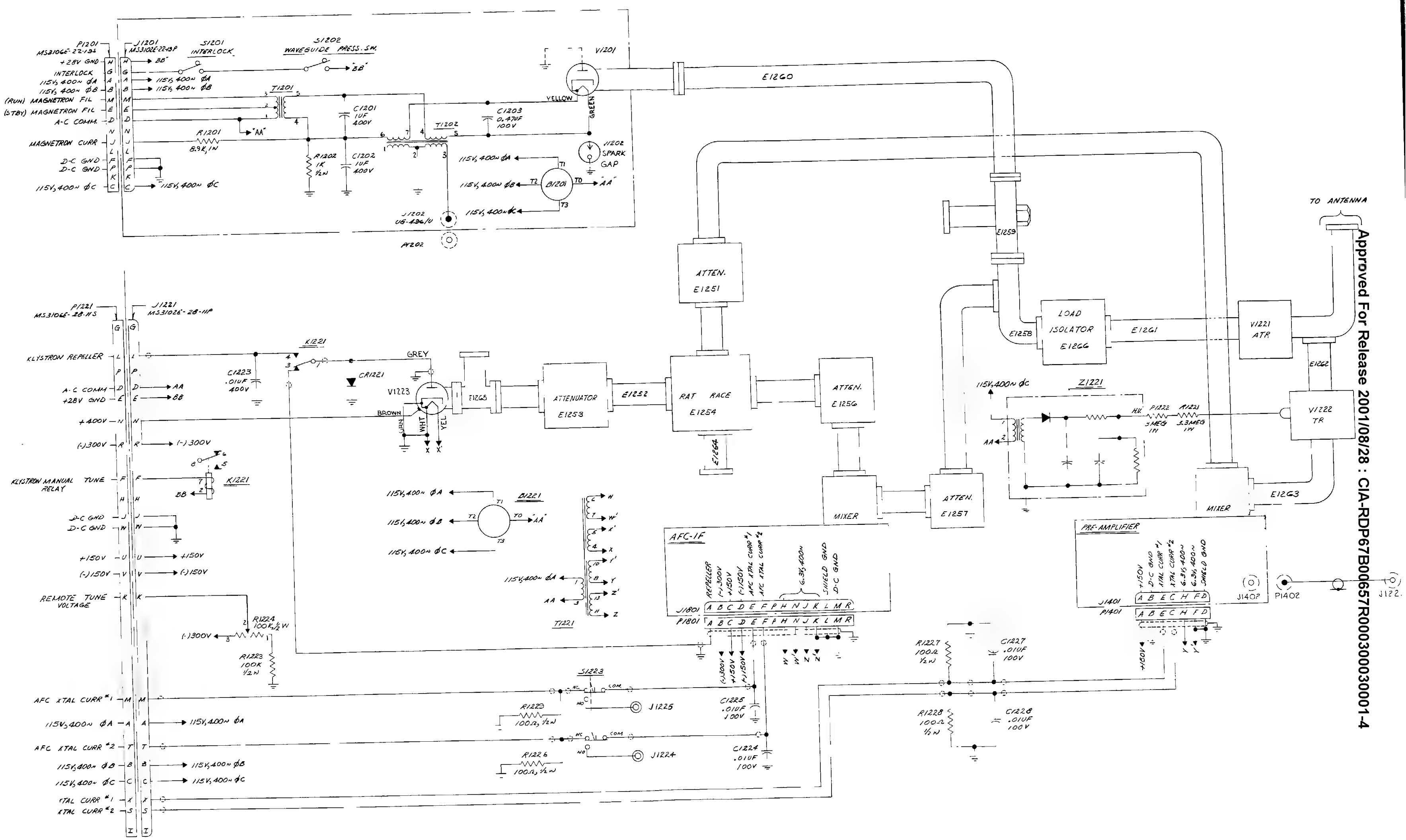
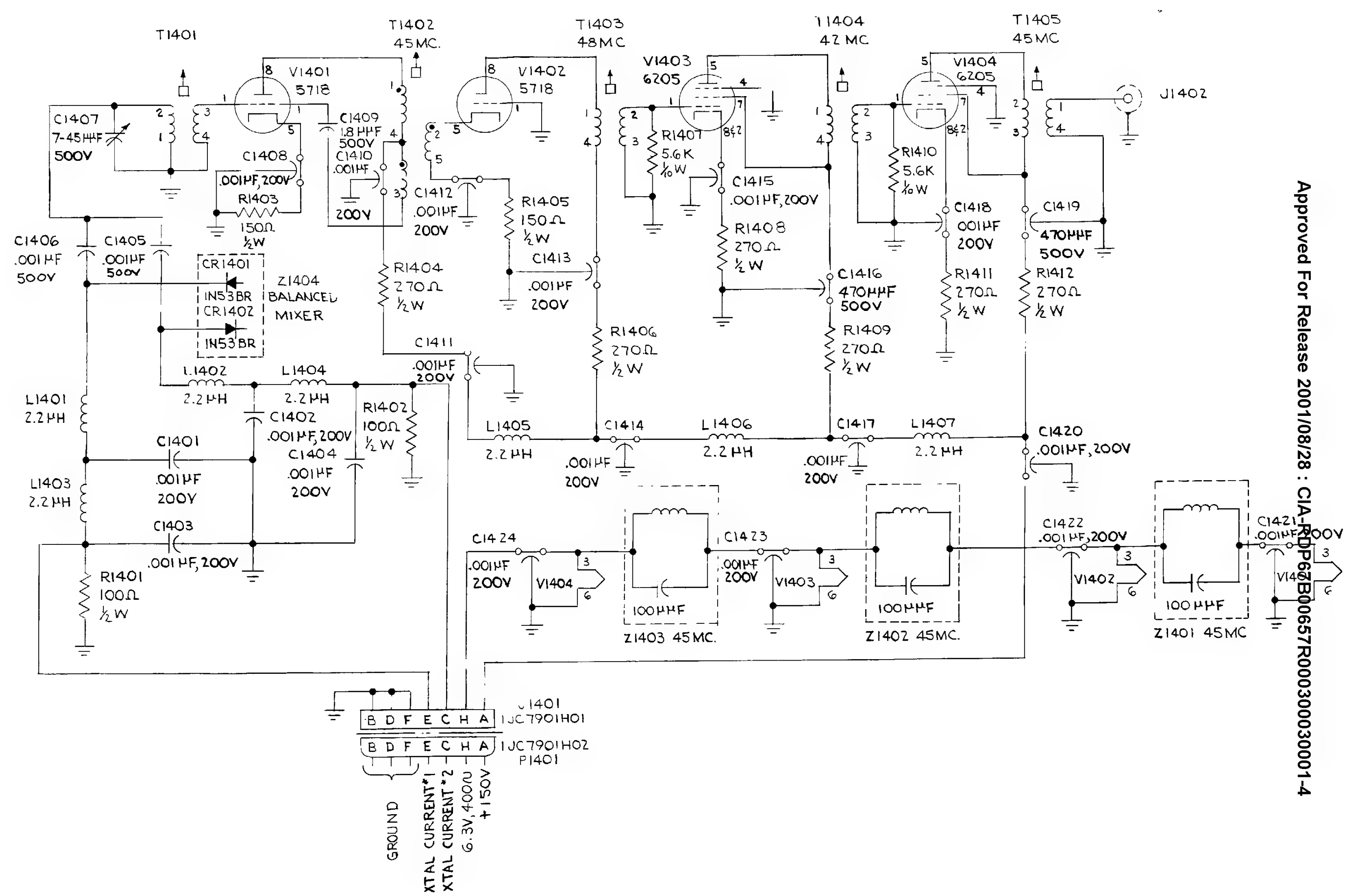


Figure 5–1. Antenna Assembly, Schematic Diagram



603R237

Figure 5-2. Receiver-Transmitter, Schematic Diagram



503R226

Figure 5–3. R–F Mixer and Preamplifier, Schematic Diagram

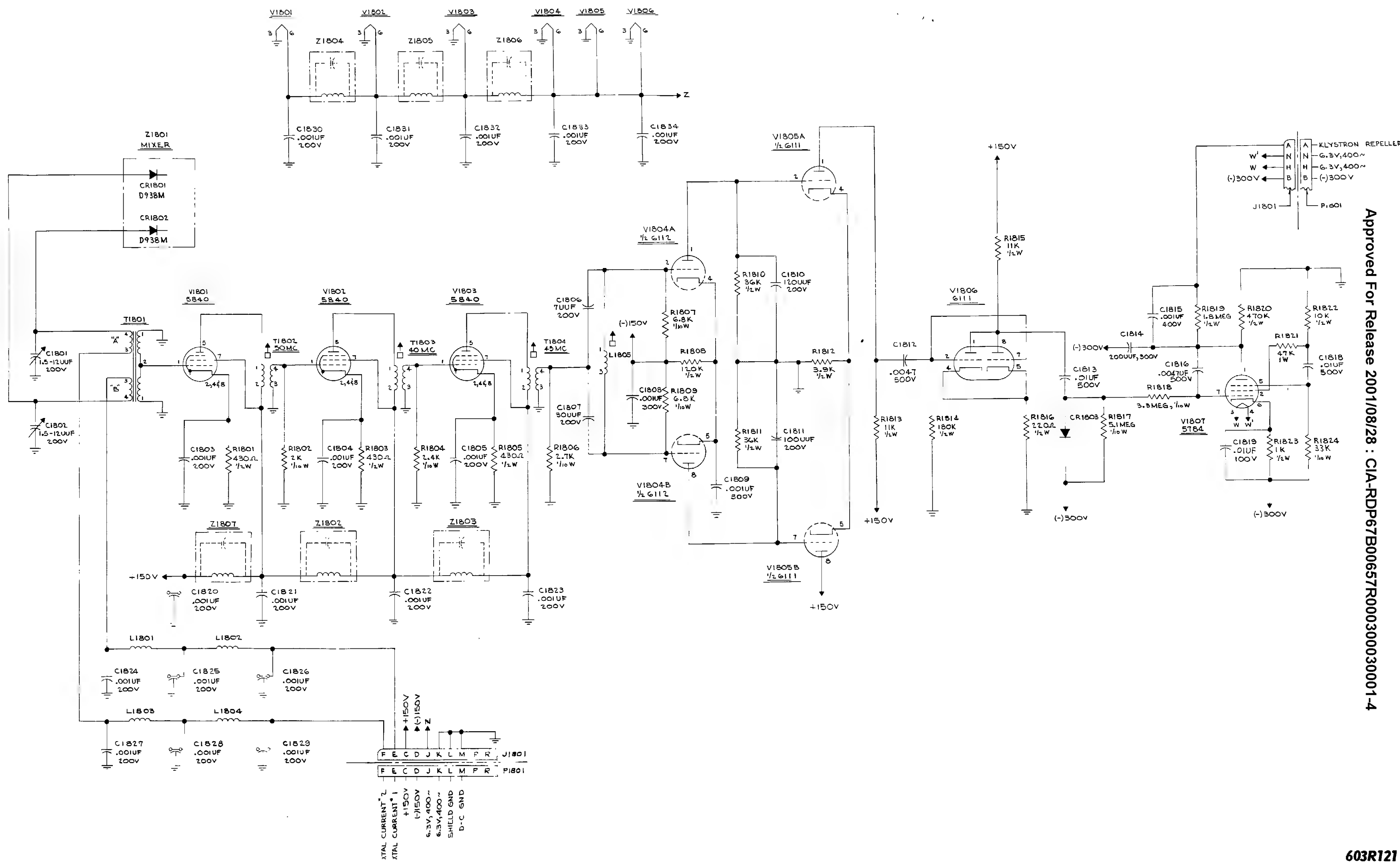
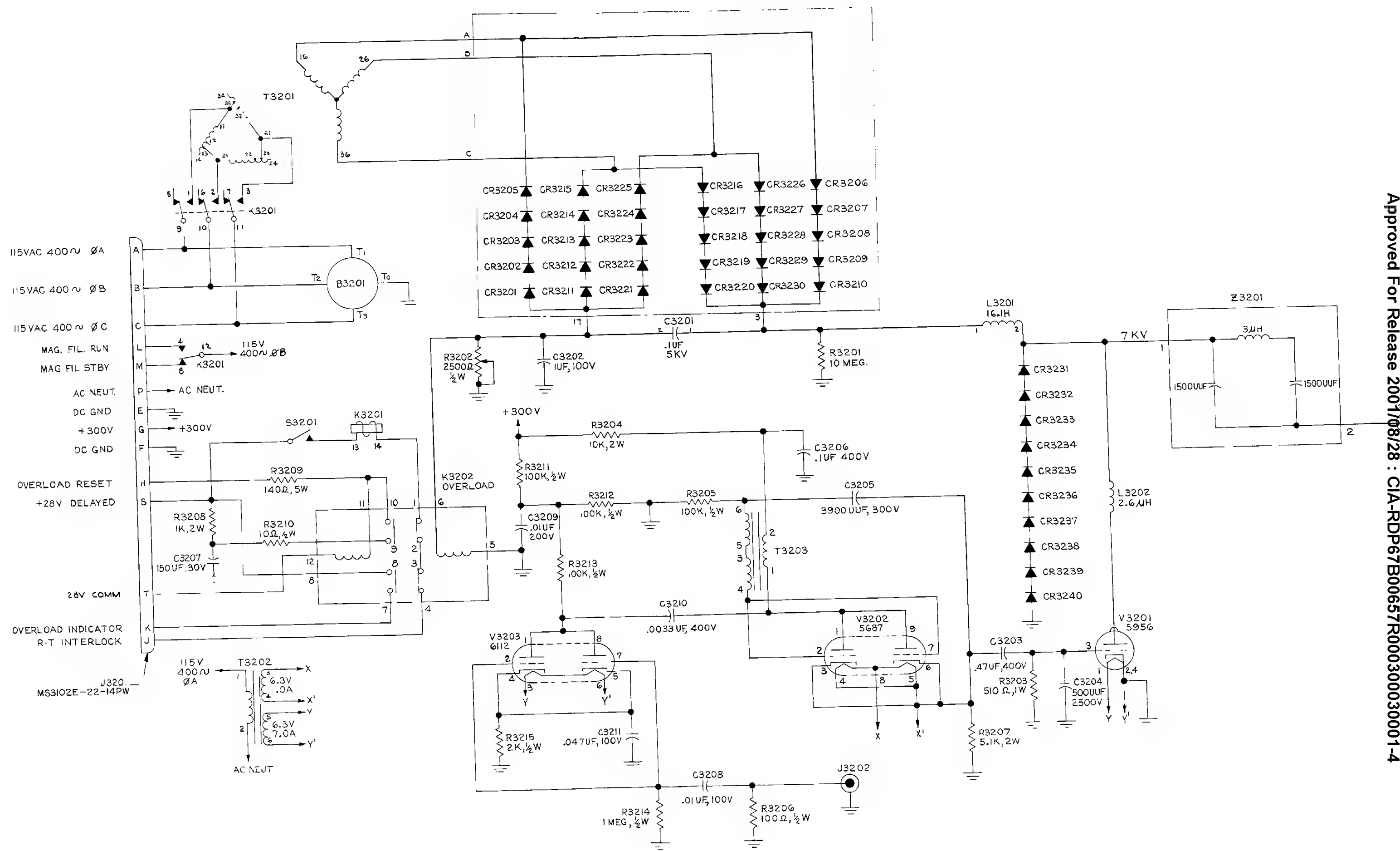


Figure 5–4. AFC, Schematic Diagram



603R198

Figure 5–5. Modulator, Schematic Diagram

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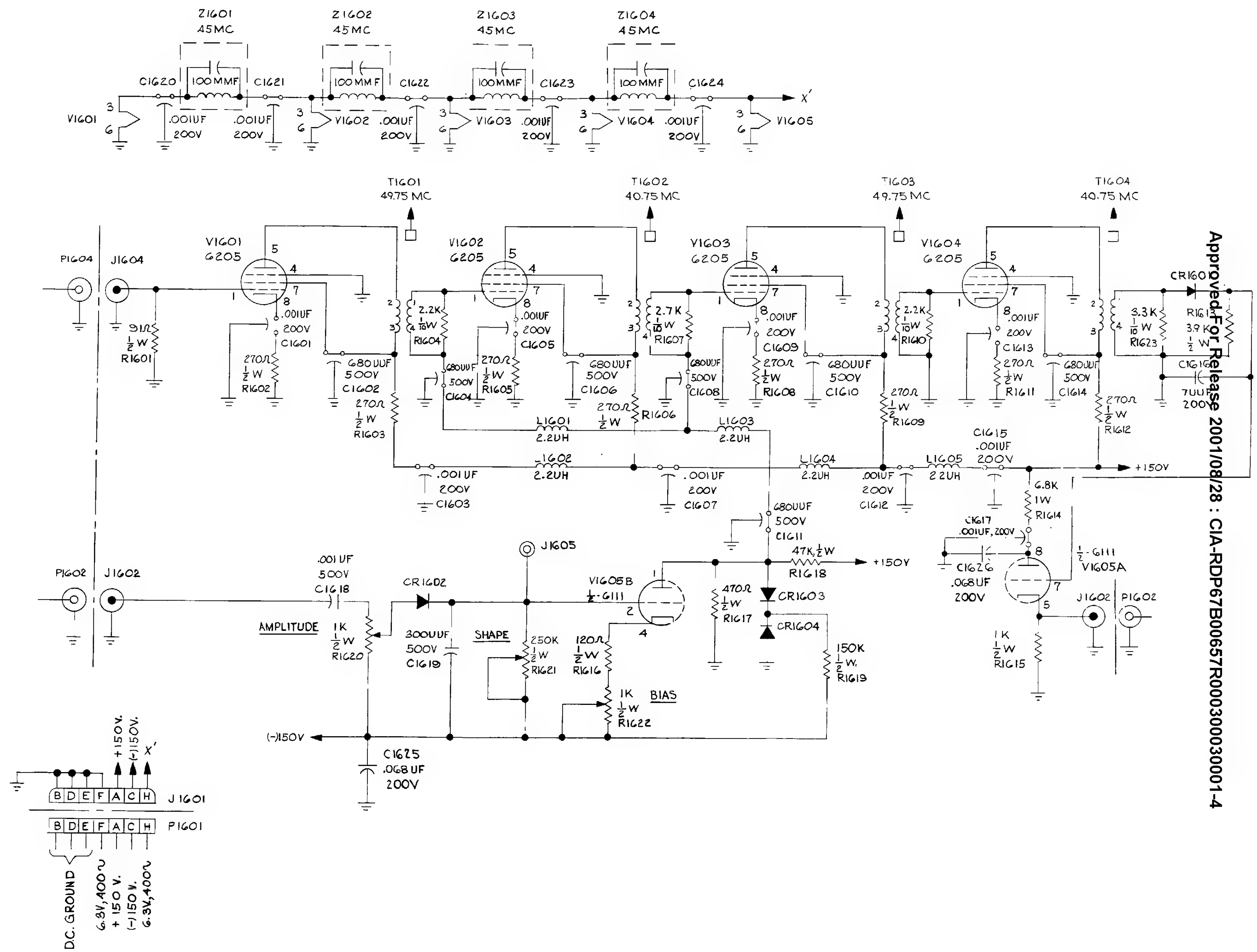

503R252

Figure 5–6. Postamplifier, Schematic Diagram

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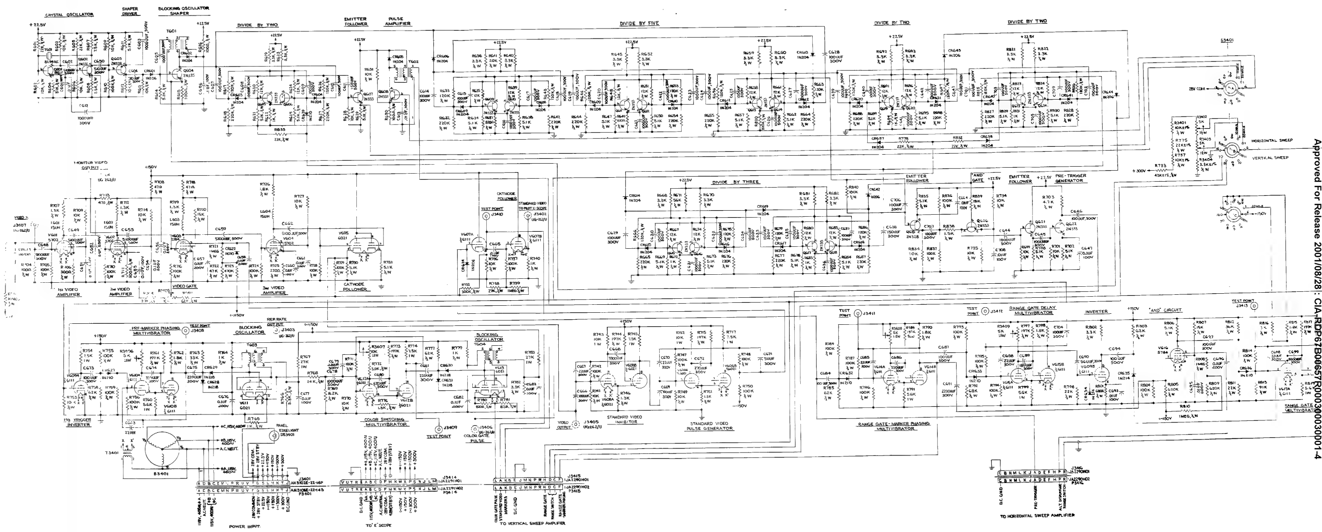

703R124

Figure 5–7. Synchronizer, Schematic Diagram

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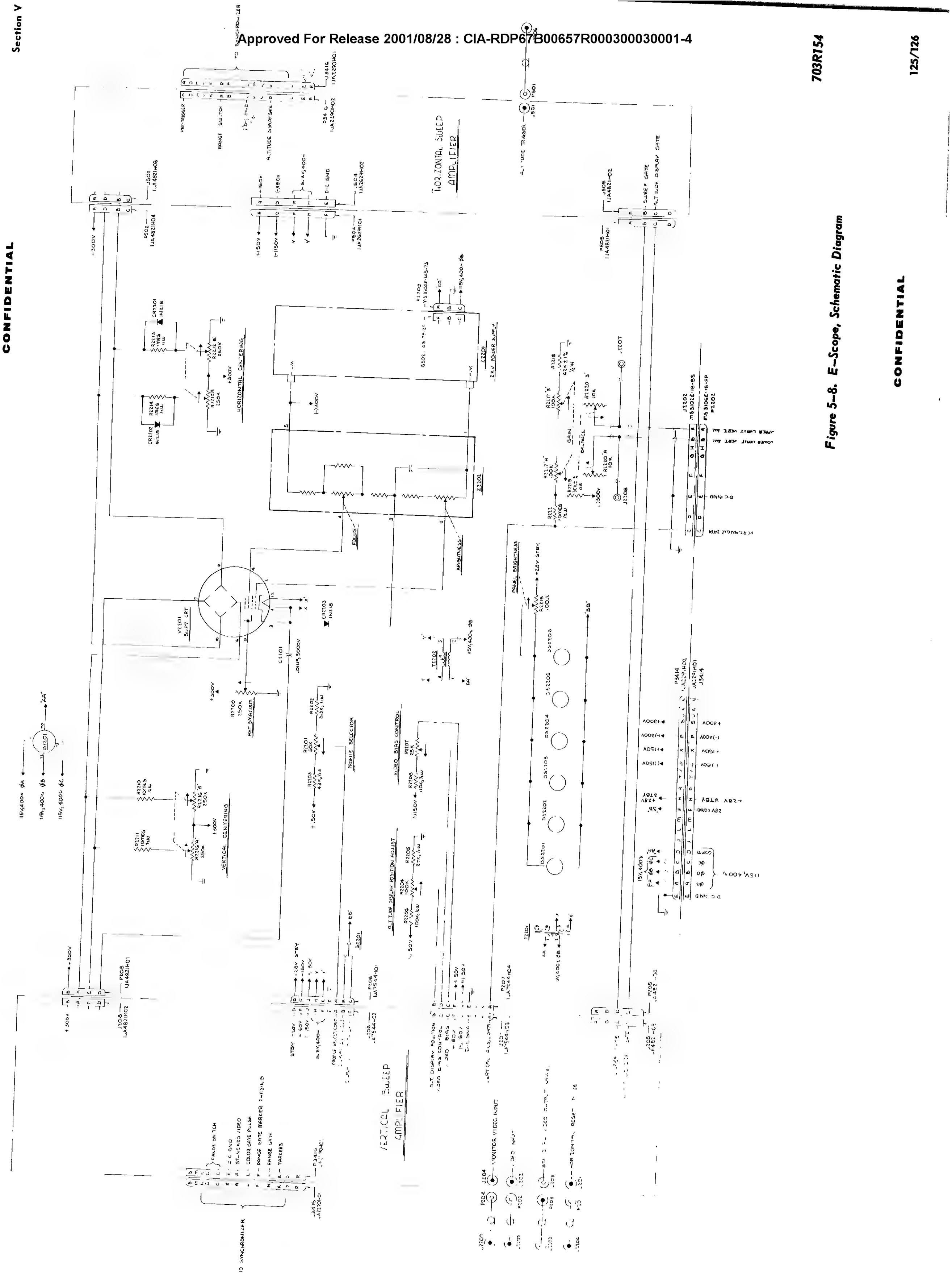

Figure 5-8. E-Scope, Schematic Diagram

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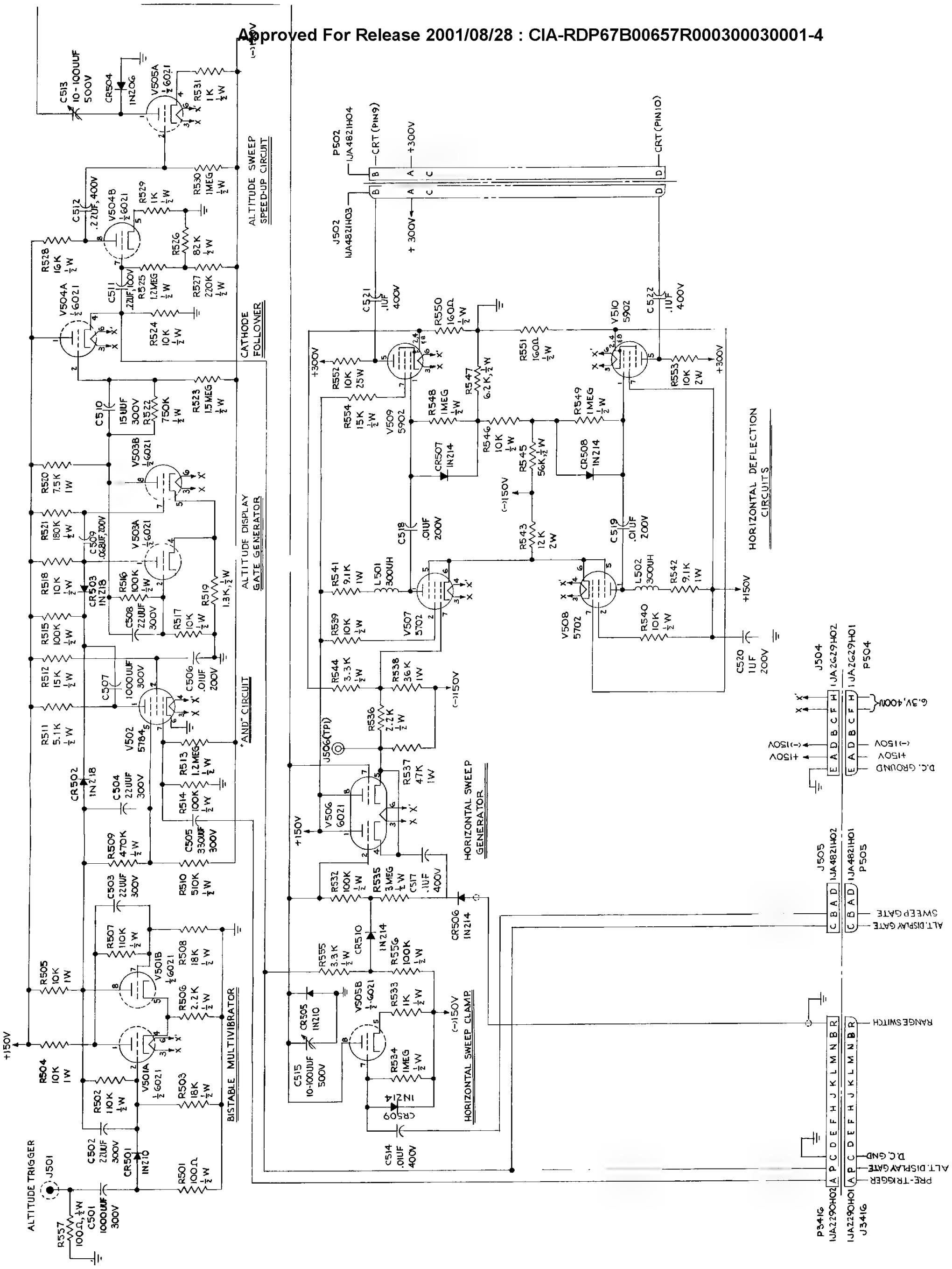
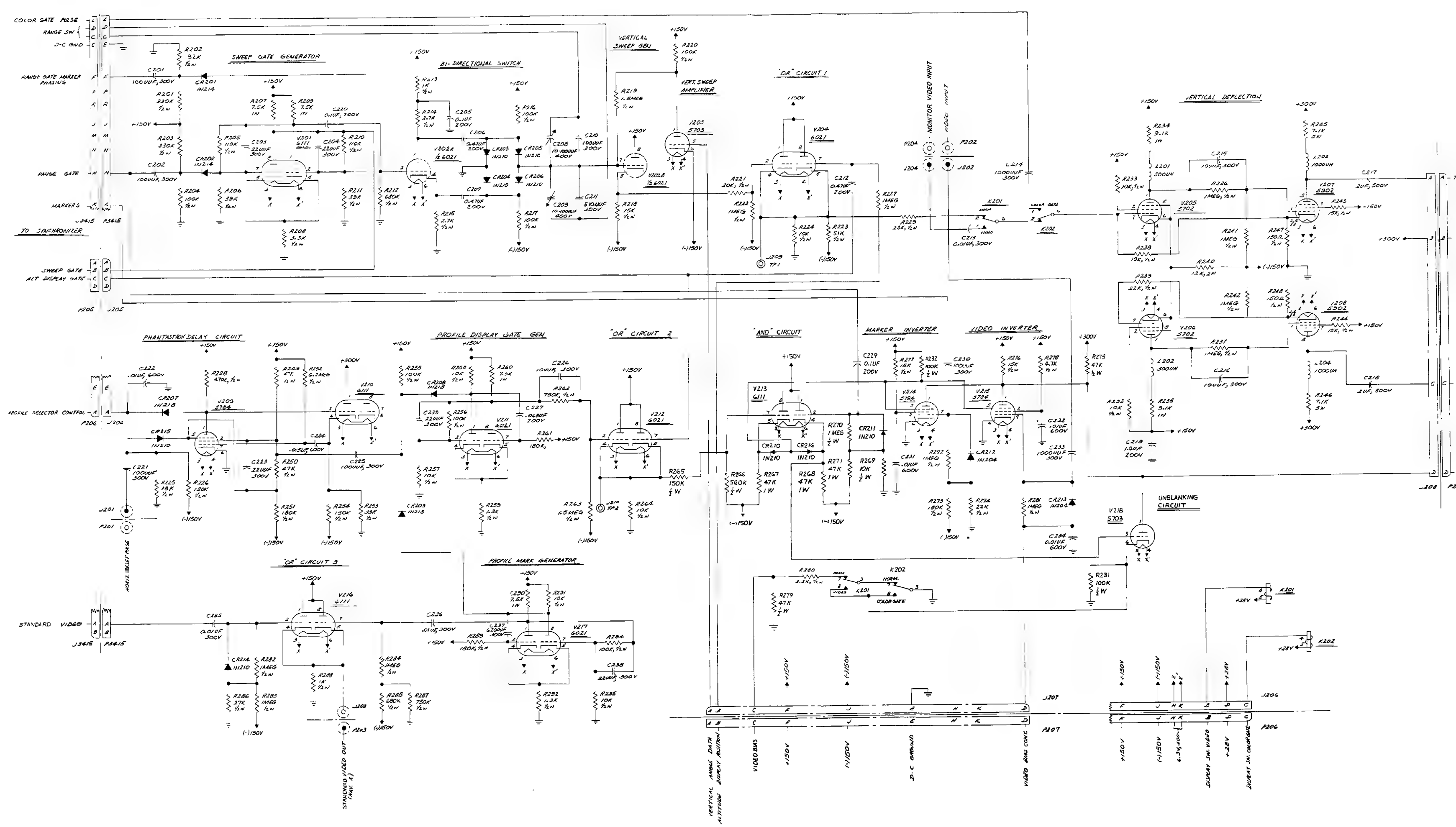


Figure 5–9. Horizontal Sweep Amplifier, Schematic Diagram



703R139

Figure 5–10. Vertical Sweep Amplifier, Schematic Diagram

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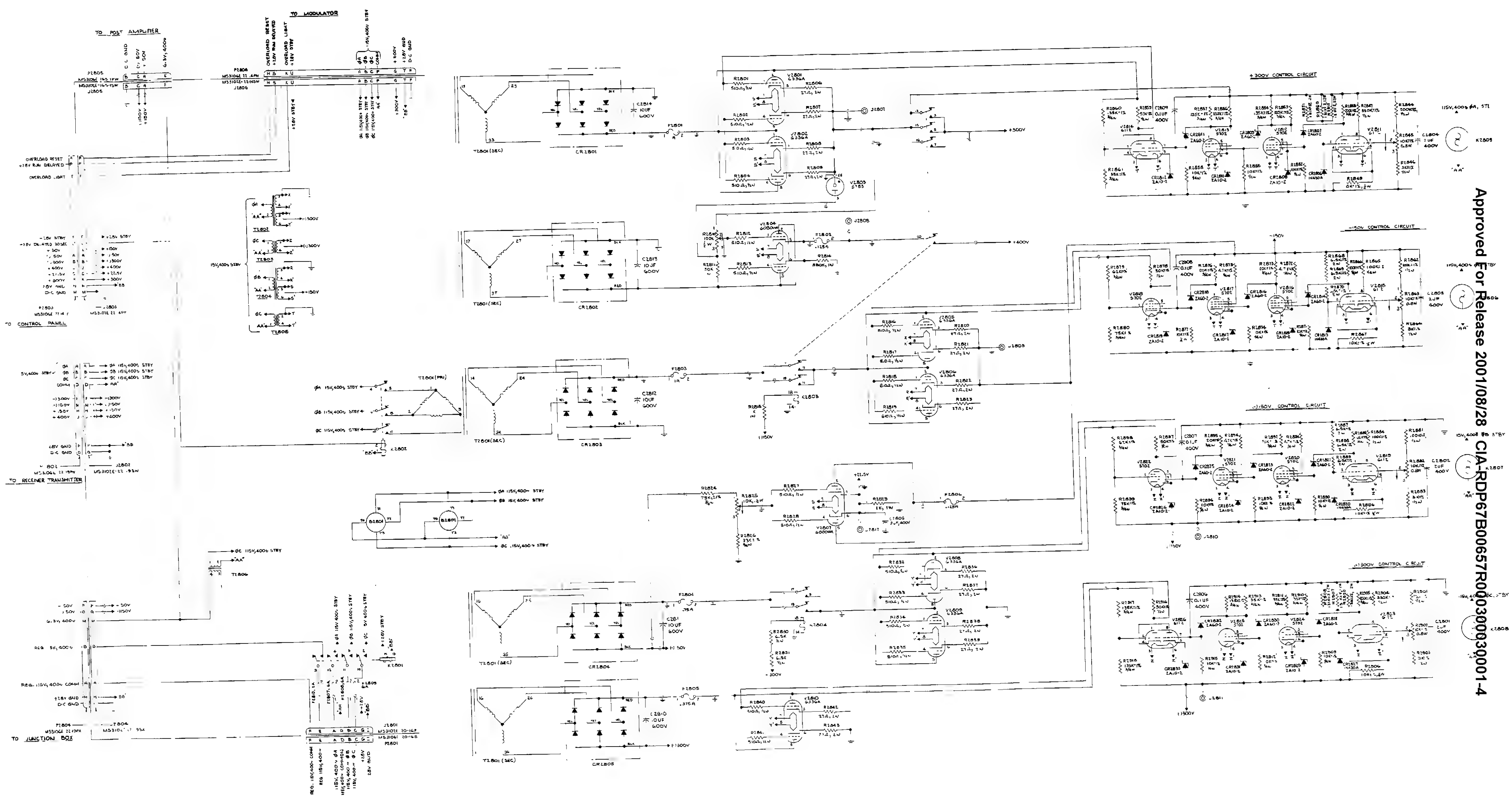

703R161

Figure 5–11. Power Supply, Schematic Diagram

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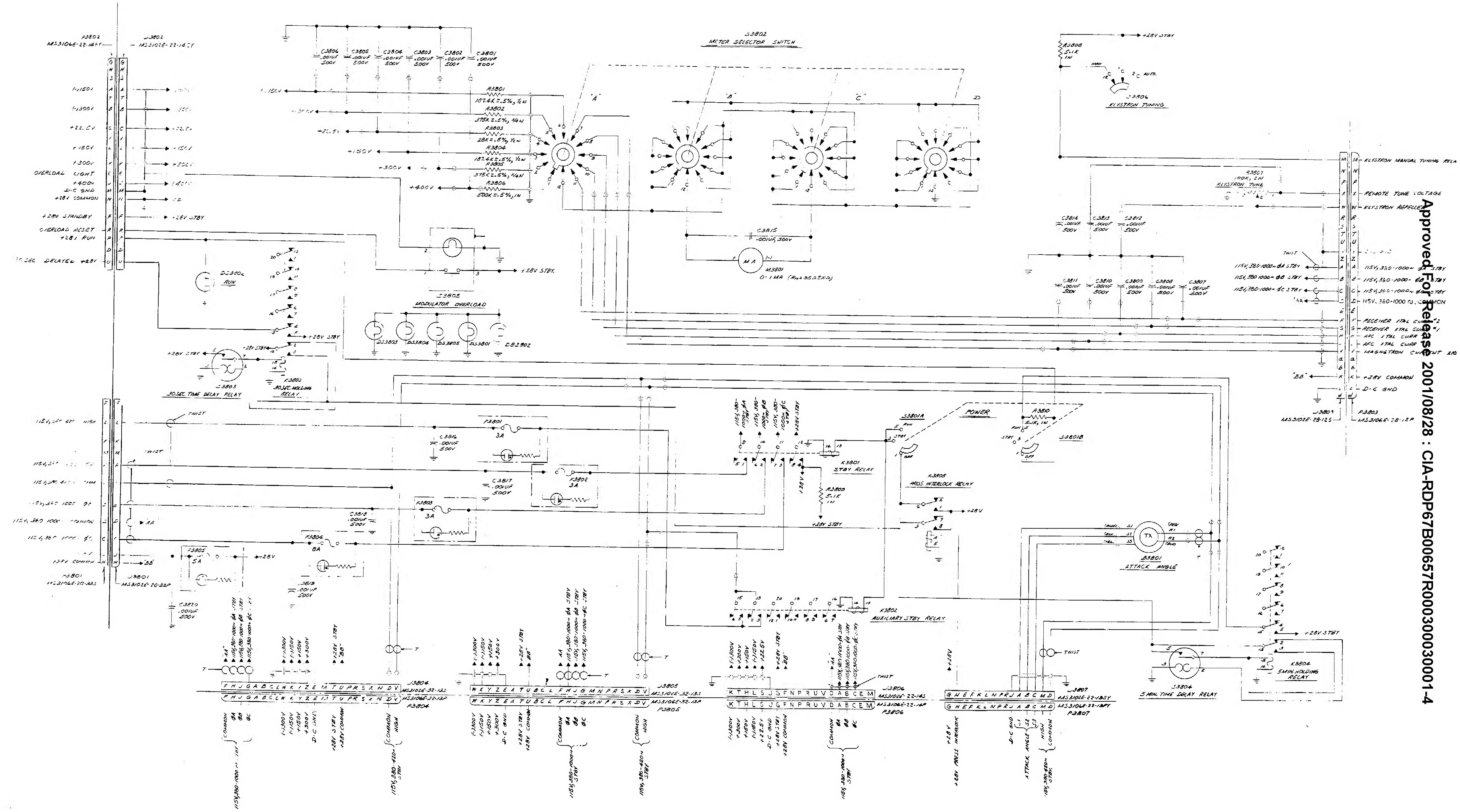

703R15.

Figure 5–12. Control Panel, Schematic Diagram

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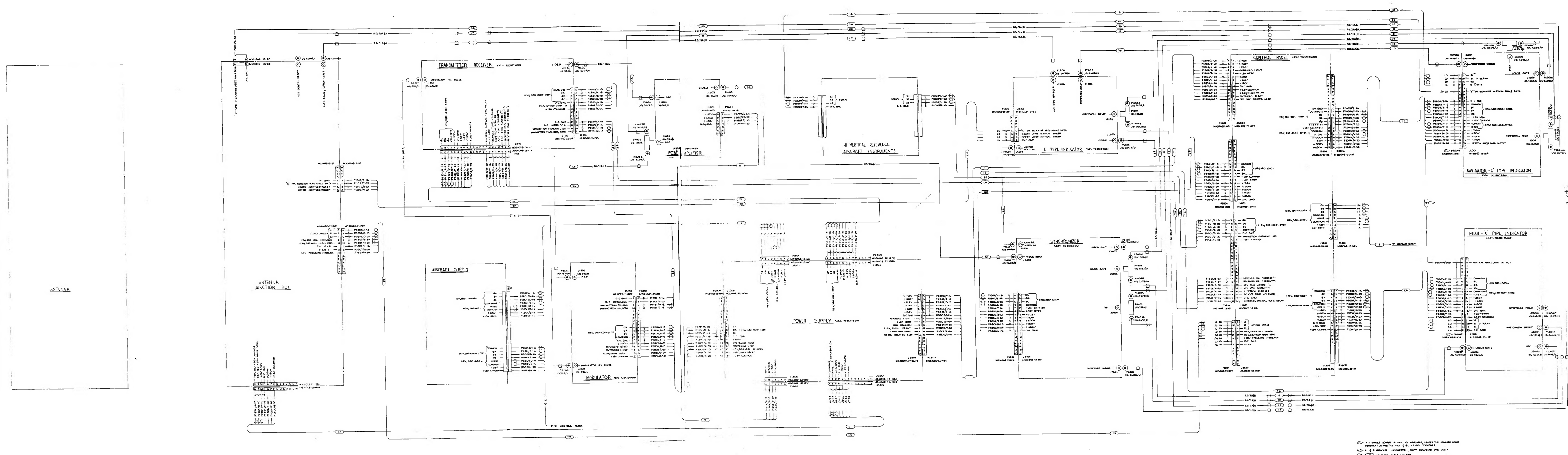
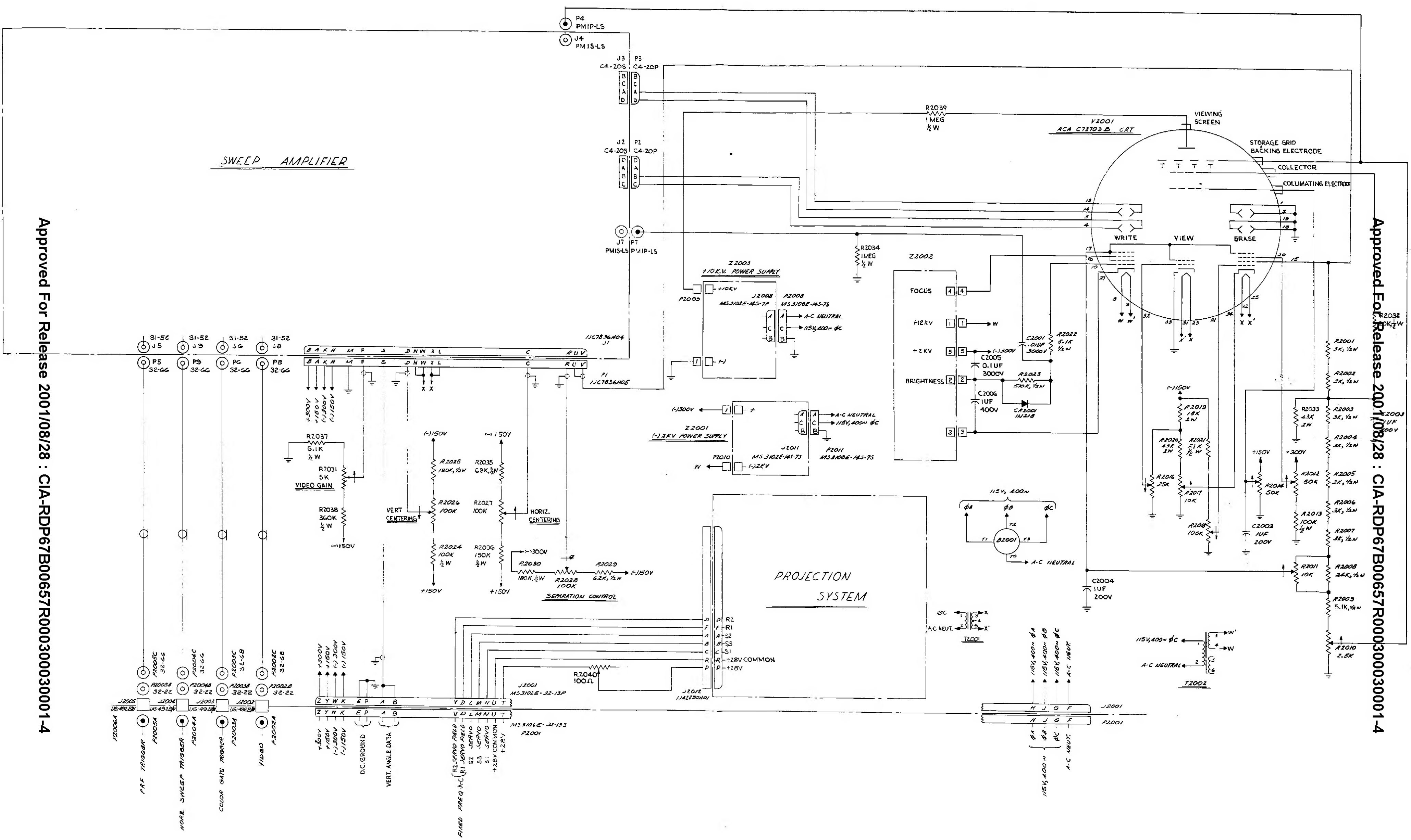


703R193

Figure 5–13. Interconnection Cable, Schematic Diagram



703R137

Figure 5–14. X–Scope, Schematic Diagram

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Westinghouse Electric Corporation

AIR ARM DIVISION

Friendship Airport Baltimore, Maryland